Illegal Experimental Tobacco Marketplace II: effects of vaping product bans — findings from the 2020 International Tobacco Control Project

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ABSTRACT

Significance Restrictive e-cigarette policies may increase purchases from illegal sources. The Illegal Experimental Tobacco Marketplace (IETM) allows examination of how restrictions impact illegal purchases. We investigated (1) the effect of a vaping ban, total flavour vaping ban and partial flavour vaping ban on the probability of purchasing illegal vaping products among different regulatory environments (USA, Canada and England) and tobacco user types (cigarette smokers, dual users and e-cigarette users); and (2) the relation between ban endorsement and illegal purchases.

Methods Participants (N=459) from the International Tobacco Control Survey rated their support of bans and chose to purchase from a hypothetical legal experimental tobacco marketplace or IETM under control and the three ban conditions.

Results In total, 25% of cigarette smokers, 67% of dual users and 79% of e-cigarette users made IETM purchases. Cross-country comparisons depicted dual users from Canada (OR: 19.8), and e-cigarette users from the USA (OR: 12.9) exhibited higher illegal purchases odds than the same user type in England. Within-country comparisons showed e-cigarette and dual users are more likely to purchase from the IETM than cigarette smokers in the most restrictive condition, with the largest effects in e-cigarette users (England—OR: 1722.6, USA—OR: 22725.3, Canada—OR: 6125.0). Increased opposition towards partial or total flavour ban was associated with increased IETM purchasing in the corresponding condition.

Conclusions Vaping restrictions may shift users’ preference to the illegal marketplace in a regulatory environment. Evidence of the IETM generalisability in a geographically dispersed sample enhances its utility in tobacco regulatory science.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Little empirical evidence exists to how e-cigarette policies may affect illegal e-cigarette purchasing. Moreover, a research gap exists as to the differential effects of these policies across national borders.

WHAT THIS STUDY ADDS

⇒ This study assessed the effects of four different e-cigarette policies (vaping ban, total flavour vaping ban, partial flavour vaping ban and no vaping ban) among three tobacco user types (exclusive e-cigarette users, dual users, exclusive cigarette smokers) across three regulatory environments (England, USA and Canada).

⇒ Among e-cigarette users, the vaping ban resulted in higher rates of illegal e-cigarette purchases in the USA compared to Canada and England; among dual users, higher odds of illegal e-cigarette purchases were observed in Canada compared with the USA and England.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings show how regulations may impact illegal tobacco and nicotine purchasing and suggest that a comprehensive package of tobacco control and e-cigarette policies may be necessary to achieve significant decreases in illegal e-cigarette use.

INTRODUCTION

Considerable evidence confirms widespread use of illegal tobacco.1 Globally, 1 in every 10 cigarettes and tobacco products is purchased illegally.2 Illegal tobacco and nicotine products may contain toxic and dangerous adulterants3 and are widely available through online purchases.4 5 Illegal tobacco trade undermines tobacco control efforts, fuels the tobacco epidemic, poses a serious threat to public health beyond authentic products and results in substantial losses in government revenues.6

More recently, an outbreak of vaping-associated lung disease in the USA7 was traced to the use of illegal non-commercial adulterated e-cigarettes.8 Governments are concerned with the increased vaping rates, estimated to be 68 million people worldwide,9 driven by youth and young adults uptake.10-15 Policies limiting access to vaping products have recently been implemented or are under debate in many countries. European Union member states have recently banned flavours. In Canada, no ‘dessert’ or ‘confectionery’ flavours may be promoted on product packaging. In the USA, the Youth Tobacco Prevention Plan proposes that flavours (except tobacco, mint and menthol) should be sold in age-restricted in-person locations.15 Most recently, the Food and Drug
Administration banned any JUUL products, the leading e-cigarette brand in the USA.16 Some evidence suggests that flavour bans have increased illegal purchases. For example, reports from Massachusetts16 and San Francisco,17 have indicated the presence of illegal trade after their flavoured vaping bans. However, prospective analyses of how policies affect illegal e-cigarette purchasing are scarce.18 19 Therefore, a scientific understanding of the consequences of regulation on consumer behaviours prior to policy implementation is warranted.

Towards this goal, the Illegal Experimental Tobacco Marketplace (IETM), a modification of the Experimental Tobacco Marketplace (ETM), may offer relevant information. The ETM mimics the real-world tobacco marketplace20 where virtual purchases can be made among various tobacco and nicotine products differing in prices,21 22 flavours,19 nicotine concentration23-25 and taxes and subsidies26-27 (see Bickel et al20 for illustrative images of the ETM). The ETM and its extension, the IETM, constitute an experimental model developed to predict public health policies prior to implementation. As an experimental model, the ETM is not a detailed replication of real-world circumstances, rather a scientific model that can identify some of the core relationships between tobacco and nicotine products and potentially relevant environmental variables. Such initial experimental evidence can prevent or mitigate unintended consequences, which are encountered with considerable frequency. As such, models provide important insights and forecasts that can contribute to the evidentiary basis for policy formation and reform.

In the IETM model, two concurrent marketplaces are available, the IETM and the Legal Experimental Tobacco Marketplace (LETM). Cheaper products or products not available in the LETM may be purchased in the IETM. This methodological extension permits measurement of the unintended consequences of regulation thereby allowing policymakers to prevent or mitigate these consequences.

Previous IETM research in the USA examined illegal purchasing as a function of three e-cigarette policy scenarios (ie, vaping ban, total flavour vaping ban and no vaping ban) across increasing cigarette prices in three tobacco user types (ie, exclusive e-cigarette users, frequent dual users and exclusive cigarette smokers).19 The likelihood of purchasing in the IETM was increased by (1) the two bans in all users, with the largest effect among exclusive e-cigarette users; (2) increasing cigarette prices in exclusive cigarette smokers and frequent dual users; and (3) a vaping ban compared with a total flavour vaping ban. Generally, the illegal marketplace substituted for the legal marketplace when accessibility (determined by product bans) and affordability (influenced by high prices) decreased. Of course, illegal market purchasing may be modulated by country-specific regulations. Moreover, the degree to which these regulatory environments influence both legal and illegal activities is unknown.

The current study replicates and extends Freitas-Lemos et al19 using a larger and geographically dispersed sample, an additional policy scenario and policy opinion data. First, we used a between (user types; see online supplemental material for between-countries comparisons) and within (conditions) repeated measures design to examine the probability of purchasing vaping products in an IETM under three e-cigarette policy scenarios and increasing cigarette prices in different regulatory environments (England, USA and Canada). The policy scenarios included a vaping ban, a total flavour vaping ban (including menthol) and a partial flavour vaping ban (excluding menthol). The effects were evaluated across different tobacco user types (exclusive e-cigarette user, dual users and exclusive cigarette smokers). Second, we examined the impact of individuals’ policy opinions, that is, prior support/opposition for bans, on purchasing in the IETM.

Two hypotheses were tested and informed by findings of Freitas-Lemos et al.19 First, we hypothesised that countries’ policies would modulate IETM purchasing resulting from e-cigarette restrictions and increasing cigarette price in the LETM. Second, an individual’s opposition to bans would predict illegal purchases. Additionally, we explored the generalisability of the IETM in this larger and more diverse sample.

**METHODS**

**Sample**

Study participants came from the International Tobacco Control (ITC) Four Country Smoking and Vaping Survey (ITC 4CV), a prospective cohort study that consists of online surveys conducted through probability-based sampling in the USA, Canada, England and Australia (https://itcproject.org/). A description of the methodological details and survey data is available in Thompson et al28 and via the ITC website (http://www.itcproject.org/methods). See online supplemental material for more details about the ITC 4CV wave 3 survey sample.

Upon completion of the main survey, eligible respondents in England, Canada and the USA were invited to participate in an additional substudy by the survey firms: Rakuten, Leger and Ipsos PA, respectively.26 Participants aged 21 years old or older were recruited between March and May 2020. Three tobacco user types (N=459) were identified from the main survey using the following eligibility criteria: (a) exclusive e-cigarette users (n=51 (USA), n=50 (Canada), n=50 (England)) if they reported daily e-cigarette use and no cigarette smoking; (b) dual cigarette/e-cigarette users (n=52 from the USA, n=50 from Canada, n=50 from England), if they reported daily cigarette and e-cigarette use; and (c) exclusive cigarette smokers (n=55 from the USA, n=51 from Canada, n=50 from England), if they reported daily cigarette smoking and no e-cigarette use. Exclusive cigarette smokers and dual users had to report at least 50% of their cigarettes as factory made (compared with roll-your-own). The target sample size in this study was estimated to be 50 participants per user type per country, consistent with a prior study.19

**Procedure**

**Experimental Tobacco Marketplace**

The substudy survey contained a Timeline Followback to report nicotine use,30 hypothetical tobacco and nicotine purchases in the LETM or the IETM, and history of illicit purchases.

**Policy scenarios**

Participants were exposed to four scenarios in a randomised order (the within-subject factor): (1) vaping ban that removed all vaping products from the legal marketplace; (2) total flavour ban that removed all flavoured vaping products except tobacco-flavoured products from the legal marketplace; (3) partial flavour ban that removed all flavoured vaping products except tobacco-flavoured and menthol-flavoured products from the legal marketplace; and (4) no vaping ban that allowed all vaping products of any flavour in the legal marketplace (control condition). For each scenario, participants were asked to imagine they were in a specific situation and shown a list of available products in each marketplace (see online supplemental material for details).
Marketplace choice
In every policy scenario, participants engaged in five price trials related to that scenario. In every price trial, participants were provided with a list of product prices in each marketplace and presented with the option to purchase tobacco and nicotine products from the LETM or the IETM. After that, they were directed to the chosen marketplace to complete a hypothetical purchase.

Hypothetical purchase
Participants were provided an experimental account balance to purchase tobacco and nicotine products for 7 days (see online supplemental material for details on how participants’ account balance was calculated).

Each marketplace displayed pictures, information (eg, nicotine dose and flavour) and prices for several tobacco and nicotine products. Participants were told their preferred brand was always available. Disposable e-cigarettes, e-liquids, pods and cartridges were available in each marketplace according to specific restrictions:
1. Vaping ban: vaping products were only available in the IETM.
2. Total flavour vaping ban: tobacco-flavoured vaping products were only available in the LETM and any flavoured vaping products (except for tobacco) were available in the IETM.
3. Partial flavour vaping ban: tobacco-flavoured and menthol-flavoured vaping products were only available in the LETM and any flavoured vaping products (except for tobacco and menthol) were available in the IETM.
4. No ban: all products were available in both LETM and IETM.

The price of conventional cigarettes available in the LETM increased across five trials on a logarithmic scale (marketprice (MP), 2×MP, 4×MP, 8×MP, 16×MP). A broad range of cigarette prices was examined across trials to fully characterise the relationship between products—thereby discerning how users defend their consumption or substitute with other products (see Aston and Cassidy31 for a review on behavioural economic methods). Other product prices in the LETM and in the IETM remained constant across trials. Tobacco and nicotine product prices were defined by computing the median prices by product category using the Nielsen 2017 data and local stores (USA) or Euromonitor 2018 (Canada and UK) (see online supplemental table 1 for tobacco and nicotine product prices per country).

ITC 4CV3 Survey
The main survey included demographics and several questions about smoking and vaping policy opinion. Germane to this study, participants were randomly asked one of the single-item questions: ‘Would you support or oppose a law that…?’ Bans fruit, candy, and other flavours in vaping products and/or e-liquid, so that ONLY TOBACCO and MENTHOL flavours would be available’ (equivalent to a partial flavour ban; n=219) or ‘Would you support or oppose a law that…?’ Bans MENTHOL, fruit, candy, and other flavours in vaping products and/or e-liquid, so that ONLY TOBACCO flavour would be available’ (equivalent to total flavour ban; n=223). Participants indicated their opinion in a 4-point Likert scale (1: strongly support to 4: strongly oppose), refused to answer or responded ‘don’t know’.

Statistical analysis
Demographics, alternative substance use and prior illegal purchasing were summarised and compared among the countries and tobacco user types using analysis of variance (ANOVA) and Fisher’s exact test, where appropriate. Cross-country and within-country marketplace preference was analysed using a mixed-effects logistic regression to assess differences between choosing the IETM and the LETM with fixed effects for policy scenarios and cigarette prices and a random effect for participants. Model selection, including cigarette price, policy scenario, tobacco user type, all second-order and third-order interactions among these variables, was performed seeking the lowest Bayesian Information Criterion (online supplemental tables 2 and 3). Results for overall model fits are reported using the type III Wald χ² test for ANOVA and post hoc comparisons are reported as CIs adjusted for multiple testing within each mixed-model analysis using False Discovery Rate32. In an exploratory analysis, we included an interaction between perspective and policy scenarios to the model described above. All results are reported as ORs and 95% CIs. R software V.3.5.1 was used for all data analyses33 and an alpha of 0.05 level was considered significant (see online supplemental materials for details).

RESULTS
Participants’ characteristics
Characteristics of the recruited sample by country are displayed in table 1. In England, tobacco users were older (p<0.001), better educated (p<0.001) and more likely to be white (p<0.001). Tobacco users in Canada and the USA (p<0.001) reported higher income. Previous illicit activity was more prevalent in Canada (see online supplemental table 4 for sample characteristics by tobacco user type).

Marketplace preference
Marketplace preference, that is, choice for LETM or IETM purchases, was modelled using a mixed-effects logistic regression. In total, 25% of cigarette smokers, 67% of dual users and 79% of e-cigarette users made IETM purchases. Cross-country comparisons are described below.

Cross-country comparisons
Examining cross-country differences is meaningful to understand how local regulatory environments may differentially affect illegal market purchases among the same user types.

E-cigarette users
Of e-cigarette users, 74% in England, 82% in the USA and 82% in Canada purchased from the IETM at least once (χ²(2)=1.3729; p=0.5033). The comparison of marketplace preference among exclusive e-cigarette users detected significant differences in country (χ²(2)=6.938; p=0.031; figure 1) and policy scenario (χ²(3)=159.758; p<0.001), no significant differences in price (χ²(1)=2.521; p=0.112), and a significant interaction between country and policy scenario (χ²(6)=46.627; p<0.001). Specifically, the vaping ban resulted in an increase in illegal market purchases from exclusive e-cigarette users in the USA compared with Canada (OR: 7.39; adjusted 95% CI: 1.12 to 48.87; see online supplemental table 5 for individual results) and England (OR: 12.91; adjusted 95% CI: 1.91 to 87.08).

Dual users
Of dual users, 52% in England, 75% in the USA and 74% in Canada purchased from the IETM at least once (χ²(2)=7.7133; p=0.0227).
Among dual users, significant differences were detected in country ($\chi^2(2)=11.799$; $p=0.003$; figure 2), with higher odds of illegal market purchases from participants from Canada (OR: 19.83; 95% CI: 3.56 to 110.37), and no significant differences from participants from the USA (OR: 3.62; 95% CI: 0.70 to 18.61) compared with participants from England; in price ($\chi^2(1)=63.895$; $p<0.001$) and in policy scenario ($\chi^2(3)=75.04$; $p<0.001$), with an e-cigarette ban (OR: 4.22; adjusted 95% CI: 2.60 to 6.61), a total flavour ban (OR: 3.31; adjusted 95% CI: 2.38 to 4.70) and a partial flavour ban (OR: 2.39; 95% CI: 1.67 to 3.39) resulting in increased utilisation of the IETM compared with no ban.

**Table 1** Demographic characteristics, smoking-related measures and illegal activity by country

|                        | England (n=152) | USA (n=151) | Canada (n=156) | $p$ value   |
|------------------------|----------------|-------------|----------------|-------------|
| Demographics           |                |             |                |             |
| Age (mean (SD))        | 49.42 (13.85)  | 46.75 (16.06)| 41.45 (14.74)  | $<0.001****$|
| Gender= male (%)       | 74 (50.3)      | 66 (42.6)   | 80 (53.3)      | 0.148†      |
| Race (%)               |                |             |                |             |
| White                  | 133 (90.5)     | 108 (69.7)  | 130 (86.7)     | $<0.001***$ |
| Non-white              | 13 (8.8)       | 47 (30.3)   | 20 (13.3)      |             |
| Not answered           | 1 (0.7)        | 0 (0.0)     | 0 (0.0)        |             |
| Education (%)          |                |             |                | $<0.001***$ |
| Low                    | 17 (11.6)      | 65 (41.9)   | 40 (26.7)      |             |
| Moderate               | 73 (49.7)      | 55 (35.5)   | 62 (41.3)      |             |
| High                   | 54 (36.7)      | 35 (22.6)   | 47 (31.3)      |             |
| Not answered           | 3 (2.0)        | 0 (0.0)     | 1 (0.7)        |             |
| Income (%)             |                |             |                | $<0.001****$|
| Low                    | 23 (15.6)      | 46 (29.7)   | 41 (27.3)      |             |
| Moderate               | 67 (45.6)      | 42 (27.1)   | 41 (27.3)      |             |
| High                   | 49 (33.3)      | 67 (43.2)   | 65 (43.3)      |             |
| Not answered           | 8 (5.4)        | 0 (0.0)     | 3 (2.0)        |             |
| Tobacco daily use (typical day during the last 30 days) |               |             |                |             |
| Cigarettes per day (mean (SD)) | 8.19 (8.47) | 8.32 (11.04) | 6.75 (8.31)    | 0.269*      |
| E-cigarette puffs per day (mean (SD)) | 50.57 (175.36) | 52.22 (109.70) | 45.83 (127.74) | 0.918*      |
| Other tobacco/nicotine product use (typical day during the last 30 days) |               |             |                |             |
| Snus (USA/Canada)/inhalator (England) (%) | 16 (10.7) | 10 (6.3) | 9 (6.0) | 0.260†      |
| Dip (eg, chewing tobacco (%) | 12 (8.0) | 10 (6.3) | 9 (6.0) | 0.777†      |
| Heated tobacco products (%) | 17 (11.3) | 14 (8.9) | 9 (6.0) | 0.270†      |
| Nicotine pouch (%)      | 9 (6.0)        | 13 (8.2)    | 7 (4.6)        | 0.444†      |
| Nicotine lozenge (%)    | 10 (6.7)       | 9 (5.7)     | 8 (5.3)        | 0.881†      |
| Nicotine gum (%)        | 10 (6.7)       | 13 (8.2)    | 12 (7.9)       | 0.904†      |
| Illegal activity        |                |             |                |             |
| Previous illicit purchase (%) | 0.005†**   |               |               |             |
| 0 times                 | 112 (74.7)     | 112 (70.9)  | 83 (55.0)      |             |
| 1–2 times               | 17 (11.3)      | 17 (10.8)   | 20 (13.3)      |             |
| 3–5 times               | 7 (4.7)        | 6 (3.8)     | 19 (12.6)      |             |
| 6–10 times              | 4 (2.7)        | 4 (2.5)     | 6 (4.0)        |             |
| More than 10 times      | 10 (6.7)       | 19 (12.0)   | 23 (15.2)      |             |
| Previous illicit tobacco/nicotine product purchase (%)| 0.080†      |               |               |             |
| 0 times                 | 16 (42.1)      | 24 (52.2)   | 23 (33.8)      |             |
| 1–2 times               | 5 (13.2)       | 8 (17.4)    | 22 (32.4)      |             |
| 3–5 times               | 8 (21.1)       | 7 (15.2)    | 13 (19.1)      |             |
| 6–10 times              | 4 (10.5)       | 0 (0.0)     | 1 (1.5)        |             |
| More than 10 times      | 5 (13.2)       | 7 (15.2)    | 9 (13.2)       |             |

Due to incomplete data between surveys, demographic variables are reported for n=151 and 149, from Canada and the USA, respectively.

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

*Indicates an ANOVA.
†Indicates Fisher’s exact test.
‡Only 38 tobacco users in England, 46 tobacco users in the USA and 68 tobacco users in Canada reported previously purchasing products from an illicit source and were included in the analysis of this question.

Cigarette smokers

Of cigarette smokers, 28% in England, 24% in the USA and 24% in Canada purchased from the IETM at least once ($\chi^2(2)=0.353$; $p=0.838$). No significant differences were identified among countries ($\chi^2(2)=0.067$; $p=0.967$; online supplemental figure 1). See online supplemental material for more details.

Additional analyses were conducted. See online supplemental figures 2–4 and online supplemental tables 6–10 for within-country comparisons. For tobacco and nicotine product purchases per tobacco user type, policy scenario and country, see online supplemental tables 11–47.
To test the hypothesis that prior perspectives on total and partial flavour bans influence rates of purchasing in the IETM, we included a measure of their support for total and partial flavour bans into our logistic regression models, respectively. First, we found a strong association between participants’ views on both the total and partial flavour bans (USA: $\chi^2(9)=51.75, p<0.001$; England: $\chi^2(9)=69.69, p<0.001$; Canada: $\chi^2(9)=73.28, p<0.001$). We observed a significant interaction between policy scenario and prior opposition for a total flavour ban ($\chi^2(3)=27.38; p<0.001$), that is, increased opposition towards a total flavour ban was associated with increased purchasing from the IETM in the total flavour ban scenario compared with those in the no ban scenario (OR: 2.78, 95% CI: 1.89 to 4.09). Similarly, we found a significant interaction between policy scenario and prior opposition for a partial flavour ban ($\chi^2(3)=27.38; p<0.001$), that is, increased opposition towards a partial flavour ban was associated with increased purchasing from the IETM in the partial flavour ban scenario compared with those in the no ban scenario (OR: 2.78, 95% CI: 1.89 to 4.09). Similarly, we found a significant interaction between policy scenario and prior opposition for a partial flavour ban ($\chi^2(3)=47.26; p<0.001$), that is, increased opposition towards a partial flavour ban was associated with increased purchasing from the IETM in the partial flavour ban scenario compared with those in the no ban scenario (OR: 4.07, 95% CI: 2.70 to 6.14). Similar trends were observed for all the other ban scenarios. As expected, the partial flavour ban policy opinions resulted in the largest effect size for the partial flavour ban scenario, and the total flavour ban policy opinions resulted in the largest effect size for the total flavour ban scenario.

**Generalisability of the ETM for illegal purchases**

We explored the generalisability of the ETM in a larger and more diverse sample compared with the results published in Freitas-Lemos et al (table 2). We qualitatively compared the effect sizes for the interactions between policy scenario and tobacco user type between studies and among countries. Overall, we observed increases in purchasing in the IETM (OR range from 1.37 to 64 035.49) for all policy scenarios and tobacco user type groups compared with cigarette smokers in the no ban scenario. Across all tobacco user types, as the regulatory restrictions increased (ie, partial flavour ban to vaping ban), purchasing in the IETM increased, with greater effects among e-cigarette users. Effect sizes were mostly larger in Canada and the USA compared with England within this current study. Taken together, while effect sizes were larger in the current study compared with the prior report, for any given scenario and tobacco user type, the rank order remained consistent and the magnitude differences may reflect country-specific factors.

**DISCUSSION**

This study extended an experimental model of an illegal tobacco marketplace across different regulatory environments. The four primary results are: (1) illegal purchases increased as a function of policy restrictions and cigarette price replicating the findings in Freitas-Lemos et al; (2) among e-cigarette users, the vaping ban resulted in higher rates of IETM purchases in the USA compared with Canada and England; (3) among dual users, higher odds of IETM purchases were observed in Canada compared with the USA and England; and (4) increased opposition towards partial or total flavour ban was associated with increased IETM purchasing in the corresponding policy scenario. We address the implications of these findings below.
Consistent with prior findings, within-country comparisons showed that e-cigarette users and dual users were more likely to purchase from the IETM compared with cigarette smokers in the most restrictive environment, with the largest effects in e-cigarette users. Cigarette smokers and dual users were more likely to purchase from the IETM as cigarette prices increased. These results are reported in the online supplemental material and discussed in Freitas-Lemos et al.19

Consistent with our first hypothesis, e-cigarette restrictions and increasing cigarette price in the LETM affected participants’ likelihood of purchasing in the IETM in a regulatory environment-dependent manner. Relevant product and promotional controls towards e-cigarettes and illegal trade controls differ across England, the USA and Canada. These regulatory environments have helped develop a unique vaping culture in each country that makes illegal market substitution more or less likely.

First, in e-cigarette users, a greater likelihood of purchasing in the IETM under a vaping ban was observed in the USA compared with Canada and England. This finding suggests that exclusive e-cigarette users in the USA are more resistant to substituting tobacco-flavoured e-cigarettes with other tobacco and nicotine products and, therefore, more sensitive to a vaping ban. E-cigarette policy in the USA is considered more liberal, compared with Canada and England, but becoming stricter.35 In the USA, consumers received earlier exposure to high levels of nicotine concentrations in e-cigarettes36 and increased exposure and perceived appeal of e-cigarette marketing37 compared with Canada and England. Moreover, different sales restrictions resulted in increased online purchasing of vaping products in the

![Figure 2](https://example.com/figure2.png)

**Figure 2** Model estimated probability of choosing the illegal marketplace with 95% CIs in four different scenarios: vaping ban, total flavour ban, partial flavour ban and no ban, as the price of conventional cigarettes increased in the legal marketplace, for dual users in England, Canada and the USA.

| Policy Scenario       | England | Canada | USA |
|-----------------------|---------|--------|-----|
| No Ban                | 0.00    | 0.00   | 0.00|
| Partial Flavor Ban    | 0.25    | 0.50   | 0.75|
| Total Flavor Ban      | 0.75    | 1.00   | 1.00|

**Table 2** Generalisability of the observed effect sizes for the interaction between policy scenario and tobacco user type in Freitas-Lemos et al.19 and the current study

|                     | Freitas-Lemos et al | England | Canada | USA  |
|---------------------|---------------------|---------|--------|------|
| Vaping ban×dual users | 1.93                | 96.97   | 3583.03| 441.15|
| Total flavour vaping ban×dual users | 1.37            | 70.87   | 3071.94| 339.2 |
| Partial flavour vaping ban×dual users | —                | 78.74   | 985.03 | 293.03|
| Vaping ban×e-cigarette users | 256.2           | 5226.26 | 10073.88| 64035.49|
| Total flavour vaping ban×e-cigarette users | 33.52          | 1360.38 | 1871.09| 1194.56|
| Partial flavour vaping ban×e-cigarette users | —               | 226.42  | 541.43 | 422.25 |

Effect sizes are reported as ORs with the reference group being the purchasing pattern of cigarette smokers in the no ban scenario. Results from Freitas-Lemos et al are repeated here for convenience. Note the partial flavoured vaping ban scenario was not considered in Freitas-Lemos et al.
USA than in Canada or England. These regulatory differences may support more illegal purchases by the US sample, because the ETM mimics an online market. Alternatively, different motivations to use tobacco-flavoured e-cigarettes could be driving these results. A previous study showed that users of tobacco flavour in Canada and the USA are more likely to vape to stay abstinent from smoking; however, no comparisons between the two countries were examined. Further research should examine motivational differences across countries to understand the differential impact of a vaping ban.

Second, in dual users, a greater likelihood of purchasing in the IETM among e-cigarette users and dual users in England may be related to the government’s embrace of e-cigarettes as a smoking cessation aid, which considers e-cigarettes as more of a replacement product than an initiation product. The significantly older age of the participants in England in this study may substantiate this approach. Product standards restrict nicotine concentration to no more than 20 mg/mL and certain ingredients including colourings, caffeine and taurine. Rules prohibit e-cigarette advertising on national TV, radio, print and online media. Scientific findings indicate a decreased exposure to e-cigarette marketing in England compared with the USA and Canada. In fact, England’s approach towards e-cigarettes has facilitated smoking cessation.

Consistent with our second hypothesis, prior opposition to total and partial flavour bans was associated with increased purchases in the IETM in the respective policy scenario. A previous study with the larger sample of the 2020 ITC Survey in Canada, England and the USA indicated that 28.3% of e-cigarette users would ‘find a way to get their banned flavour(s)’ if a total flavour ban was in place. This answer was more common in exclusive vapers, daily vapers and those who were opposed to the ban. Purchasing vaping products illegally is one of the ways users could get their preferred flavours. Differences in the inclusion criteria between their study (vape at least weekly) and our study (vape daily) may account for the smaller proportion of individuals (28.3% vs 73.1%) with illegal purchase intentions in the larger sample. While policy opinion data may be useful to predict the likelihood of illegal purchases, it does not reveal potential strategies to move users away from this route. The IETM provides an opportunity to understand tobacco and nicotine product purchases in situations where products are more expensive or unavailable and an array of alternative products are legally available, therefore, providing valuable information to design policies to reduce the population’s harm from tobacco use and achieve tobacco control.

Finally, effect sizes of policy scenarios among tobacco user types compared across countries and studies were generalisable. This finding supports the ETM framework as a method to examine a range of regulatory environments to determine the relative impact of tobacco control. Moreover, the ETM could examine the causal effect of new regulations using data from before and after policy implementation. The application of the ETM framework across and within multiple regulatory environments over time enhances its utility in tobacco regulatory science.

This study is not without limitations. First, participants could only choose one marketplace per trial, which could potentially have impacted their choice. However, the mere one decision of choosing the IETM indicates the participants willingness to seek out alternatives. Note that to prevent ‘sampling’ among marketplaces, detailed instructions on available products in each marketplace were provided. Future studies should allow participants to purchase from legal and illegal sources. Second, the hypothetical nature of the tasks may represent a threat to external validity. Nevertheless, several investigations have demonstrated that hypothetical tobacco and nicotine purchasing is correlated with real-world use, including the ETM, therefore supporting the validity and reliability of the hypothetical ETM to assess purchasing and substitution of tobacco and nicotine products. Third, although the ITC sample is representative of each country’s national population, we used a small subset of this larger sample. As a result, these conclusions may not be representative of larger epidemiological outcomes. Future investigations may recruit larger and more representative samples to examine the applicability of these findings. Fourth, consequences for purchasing in the illegal market were not presented to participants; however, a prior study has shown that purchasing from the illegal marketplace, even in the absence of hypothetical penalties, was associated with higher levels of psychological effects compared with legal purchasing. Fifth, this study focused on examining conditions that may engender illegal purchases, such as different e-cigarette bans. Future studies should consider examining conditions that may mitigate illegal purchases. Lastly, we focus our analysis on which market a participant purchased from rather than the specific products purchased from each market. Consideration for this additional layer in future studies may provide insights into product preferences across markets.

In conclusion, our findings show the differential impact of regulatory environments on substitution of the illegal for the legal tobacco marketplace, thereby suggesting the implementation of vaping bans needs to be considered in the context of other tobacco control policies to mitigate illegal purchases. A comprehensive package of tobacco control and e-cigarette policies may be necessary to achieve significant decreases in illegal e-cigarette use. Similarly, the interpretation of research findings needs to consider participants’ context and background. Moreover, this study reaffirms the utility and versatility of the ETM framework across and within multiple regulatory environments over time enhances its utility in tobacco regulatory science. Further investigation is needed comparing the IETM with other measures of illegal tobacco and nicotine purchases to determine its validity.

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**Contributors** GTF is the guarantor for the ITC portion of this study and WKB is the guarantor for the ETM portion of the study; they accept full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the
decision to publish. RF-L, JSS, ANT and WB contributed to the conception and design of the study. RF-L, JSS and BAK developed the study materials. RF-L coordinated data collection of the substudy. RF-L and ANT performed the analyses. RF-L and ANT wrote the first draft of the manuscript. WB supervised the study. All authors revised the manuscript for important intellectual content and approved the final version.

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Competing interests Although the following activities/relationships do not create a conflict of interest pertaining to this manuscript, in the interest of full disclosure, WB would like to report the following: WB is a principal of HealthSim, BEAM Diagnostics and Red 5 Group. In addition, he serves on the scientific advisory board for Sober Grid and Ria Health, is a consultant for Alkermes and works on a project supported by Indvor.

Patient consent for publication Not required.

Ethics approval This involves human participants and study questionnaires and materials were reviewed and provided clearance by Research Ethics Committees at the following institutions: University of Waterloo (Canada, ORE#20803/30570, ORE#21609/30878), King’s College London, UK (REC3M-17/18-2240) and Medical University of South Carolina (waived due to minimal risk). The ETM study was also reviewed and approved by Virginia Polytechnic Institute and State University (VT-18B #117-989). Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. ITC data are available upon reasonable request. In each country participating in the International Tobacco Control Policy Evaluation (ITC) Project, the data are jointly owned by the lead researcher(s) in that country and the ITC Project at the University of Waterloo. Data from the ITC Project are available to approved researchers 2 years after the date of issuance of cleaned data sets by the ITC Data Management Centre. Researchers interested in using ITC data are required to apply for approval by submitting an International Tobacco Control Data Repository (ITCDR) request application and subsequently signing an ITCDR Data Usage Agreement. The criteria for data usage approval and the contents of the Data Usage Agreement are described online (http://www.itcproject.org). ITCM data are available upon request to WB (wkbickel@vtc.vt.edu).

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REFERENCES

1 Dutta S. Confronting illicit tobacco trade: a global review of country experiences. In: World Bank group global tobacco control program. Washington, DC: World Bank, 2019.

2 World Health Organization. Available: https://www.who.int/news-room/fact-sheets/detail/illicit-tobacco [Accessed 26 Feb 2022].

3 Stephens WE, Calder A, Newton J. Source and health implications of high toxic metal concentrations in illicit tobacco products. Environ Sci Technol 2005;39:479–88.

4 Barrera V, Malm A, Décaë-hetu D, et al. Size and scope of the tobacco trade on the darkweb. Global Crime 2019;20:26–44.

5 Office of the commissioner. FDA, DEA seize 44 websites advertising sale of illicit THC vaping cartridges to US consumers as part of operation vapor lock, 2019. Available: https://www.fda.gov/news-events/press-announcements/fda-dea-seize-44-websites-advertising-sale-illicit-thc-vaping-cartridges-us-consumers-part-operation [Accessed 27 Feb 2022].

6 Organization WH, Others. Protocol to eliminate illicit trade in tobacco products, 2013. Available: https://apps.who.int/iris/bitstream/handle/10665/80873/9789244505243-rus.pdf

7 CDC’s Office on Smoking. Health. Smoking and Tobacco Use; Electronic Cigarettes. Available: https://www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html [Accessed 12 Dec 2019].

8 Pray IW, Atti SK, Tomassello CE, et al. E-cigarette, or Vaping, Product Use-Associated Lung Injury Among Clusters of Patients Reporting Shared Product Use - Wisconsin, 2019. MMWR Morb Mortal Wkly Rep 2020;69:236–40.

9 Jerzyński T, Simston GV, Shapiro H, et al. Estimation of the global number of e-cigarette users in 2020. Harm Reduct J 2021;18:109.

10 Shang C, Huang J, Chaloupka FJ, et al. The impact of flavour, device type and warning messages on youth preferences for electronic nicotine delivery systems: evidence from an online discrete choice experiment. Tob Control 2018;27:152–9.

11 Dai H, Leventhal AM. Prevalence of e-cigarette use among adults in the United States, 2014-2018. JAMA 2019;322:322.

12 Gentzke AS, Creamer M, Cullen KA, et al. Vital Signs: Tobacco Product Use Among Middle and High School Students - United States, 2011-2018. MMWR Morb Mortal Wkly Rep 2019;68:157–64.

13 Reid JL, Hammond D, Rynard VL. Tobacco Use in Canada: Patterns and Trends. In: Waterloo ON, ed. Canada: Propel centre for population health impact, University of Waterloo, 2019, 2019.

14 Baud L, Mckintosh A, Eastwood B, et al. Young People’s Use of E-Cigarettes across the United Kingdom: Findings from Five Surveys 2015–2017. Int J Environ Res Public Health 2017;14:973.

15 Snell LM, Nicksic N, Panteli D, et al. Emerging electronic cigarette policies in European member states, Canada, and the United States. Health Policy 2021;125:425–35.

16 Dor illegal tobacco Task force. Mass.gov. Available: https://www.mass.gov/info-details/dor-illegal-tobacco-task-force [Accessed 28 Jun 2022].

17 Yang Y, Lindblom EN, Salloum RG, et al. The impact of a comprehensive tobacco product flavor ban in San Francisco among young adults. Addict Behav Rep 2020;11:100273.

18 Gravely S, Smith DM, Liber AC, et al. Responses to potential nicotine vaping product flavor restrictions among regular vapers using non-tobacco flavors: findings from the 2020 ITC smoking and vaping survey in Canada, England and the United States. Addict Behav 2022;125:107152.

19 Freitas-Lemos R, Stein JS, Tegege AN, et al. The illegal experimental tobacco marketplace I: effects of vaping product bans. Nicotine Tob Res 2021;23:1744–53.

20 Bickel WK, Pope DA, Kaplan BA, et al. Electronic cigarette substitution in the experimental tobacco marketplace: a review. Prev Med 2018;117:98–106.

21 Quisenberry AJ, Koffarnus MN, Hatz LE, et al. The experimental tobacco marketplace I: substitutability as a function of the price of conventional cigarettes. Nicotine Tob Res 2016;18:1642–8.

22 Quisenberry A, Koffarnus MN, Bianco A, et al. The experimental tobacco marketplace II: substitutability in dual e-cigarette and cigarette users. Drug Alcohol Depend 2017;171:e171.

23 Pope DA, Poe L, Stein JS, et al. Experimental tobacco marketplace: substitutability of e-cigarette liquid for cigarettes as a function of nicotine strength. Tob Control 2019;28:206–11.

24 Kaplan BA, Pope DA, Dehart WB. Estimating uptake for Reduced-nicotine cigarettes using behavioral economics. Tobacco regulatory, 2019. Available: https://www.ingentaconnect.com/content/trsg/trs/2019/00000005/00000003/art00005.

25 Kaplan BA, Koffarnus MN, Franc CT, et al. Effects of Reduced-Nicotine cigarettes across regulatory environments in the experimental tobacco marketplace: a randomized trial. Nicotine Tob Res 2021;23:1123–32.

26 Pope DA, Poe L, Stein JS, et al. The experimental tobacco marketplace: demand and substitutability as a function of cigarette taxes and e-liquid subsidies. Nicotine Tob Res 2020;22:782–90.

27 Freitas-Lemos R, Keith DR, Tegege AN, et al. Estimating the impact of tobacco parity and harm reduction Tax proposals using the experimental tobacco marketplace. Int J Environ Res Public Health 2021;18: doi:10.3390/ijerph18157835. [Epub ahead of print: 23 07 2021].

28 Thompson ME, Fong GT, Hammond D, et al. Methods of the International tobacco control (ITC) four country survey. Tob Control 2006;15 Suppl 3:ii12–18.

29 ITC Project (2020, October). ITC Four Country Smoking and Vaping Survey, Wave 3 (ACY3, 2020) Preliminary Technical Report. University of Waterloo, Waterloo, Ontario, Canada; Medical University of South Carolina, Charleston, South Carolina, United States; Cancer Council Victoria, Melbourne, Australia; The University of Queensland, Australia; King’s College London, London, United Kingdom. Available: https://itcproject.s3.amazonaws.com/uploads/documents/ITC-ACY3_Preliminary_Technical_Report-_23Oct2020.pdf.

30 Sobell LC, Sobell MB, Follow-Back T. Timeline Follow-Back. In: Litten RZ, Allen JP, eds. Measuring alcohol consumption: psychosocial and biochemical methods. Totowa, NJ: Humana Press, 1992; 41–72.

31 Aston ER, Cassidy RN. Behavioral economic demand assessments in the addictions. Curr Opin Pharmacol 2019;30:42–7.
Original research

32 Eifrid JT, Nielsen SS. A method to compute multiplicity corrected confidence intervals for odds ratios and other relative effect estimates. *Int J Environ Res Public Health* 2008;5:394–8.

33 R Core Team. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2018. Available: https://www.R-project.org/

34 Rose A, Filion KB, Eisenberg MJ, et al. Electronic cigarettes: a comparison of national regulatory approaches. *Can J Public Health* 2015;106:e450–3.

35 U.S. Food and Drug Administration. Office of the Commissioner. FDA finalizes enforcement policy on unauthorized flavored cartridge-based e-cigarettes that appeal to children, including fruit and mint, 2020. Available: https://www.fda.gov/news-events/press-announcements/fda-finalizes-enforcement-policy-unauthorized-flavored-cartridge-based-e-cigarettes-appeal-children. [Accessed 7 Mar 2022].

36 Romberg AR, Miller Lo EJ, Cuccia AF, et al. Patterns of nicotine concentrations in electronic cigarettes sold in the United States, 2013-2018. *Drug Alcohol Depend* 2019;203:1–7.

37 Cho YJ, Thrasher JF, Driezen P, et al. Trends in exposure to and perceptions of e-cigarette marketing among youth in England, Canada and the United States between 2017 and 2019. *Health Educ Res* 2022;36:657–68.

38 Braak DC, Cummings KM, Nahhas GJ, et al. Narrative theory V: narratives about e-cigarettes influence the effectiveness of e-cigarettes for smoking cessation?: longitudinal findings from the ITC four country survey. *Nicotine Tob Res* 2017;19:1268–76.

39 Freitas-Lemos R, Tegge AN, Athanassie LN, et al. Narrative theory V: narratives about penalties resulting from illegal tobacco purchases increase psychological distress. *Exp Clin Psychopharmacol* 2022. doi:10.1037/pha0000561. [Epub ahead of print: 24 Feb 2022].

40 A public health approach to Nicotine-containing Vaping devices. Available: https://www.cpha.ca/public-health-approach-nicotine-containing-vaping-devices. [Accessed 6 Mar 2022].

41 NHS website. Using e-cigarettes to stop smoking. nhs.uk. Available: https://www.nhs.uk/live-well/quit-smoking/using-e-cigarettes-to-stop-smoking/. [Accessed 8 Mar 2022].

42 Heckman BW, Cummings KM, Hirsch AA, et al. A novel method for evaluating the acceptability of substitutes for cigarettes: the experimental tobacco marketplace. *Tob Regul Sci* 2017;3:266–79.

43 Wilson AG, Franck CT, Koffarnus MN, et al. Behavioral economic tobacco demand in relation to cigarette consumption and nicotine dependence: a meta-analysis of cross-sectional relationships. *Addiction* 2019;114:1926–40.

44 Hajek P, Phillips-Waller A, Przulj D, et al. A randomized trial of e-cigarettes versus Nicotine-Replacement therapy. *N Engl J Med* 2019;380:629–37.

45 Gonzalez-Roz A, Jackson J, Murphy C, et al. Does the regulatory environment for e-cigarettes influence the effectiveness of e-cigarettes for smoking cessation?: longitudinal findings from the ITC four country survey. *Nicotine Tob Res* 2022;36:657–68.

46 Smith TT, Nahhas GJ, Borland R, et al. Which tobacco control policies do smokers support? findings from the International tobacco control four country smoking and vaping survey. *Prev Med* 2021;149:106600.

47 Yong H-H, Hitchman SC, Cummings KM, et al. The tobacco and related products regulations 2016, 2016. Available: https://www.legislation.gov.uk/uksi/2016/507/contents/made [Accessed 6 Mar 2022].