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E-cigarette Product Preferences among Adult Smokers: A Discrete Choice Experiment

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Abstract

Objectives: In this study, we used a discrete choice experiment (DCE) conducted August-October 2017 to examine electronic nicotine delivery systems (ENDS) product preferences in a national sample of adult smokers (N = 1154) who were also using ENDS or had not ruled out future use.

Methods: The DCE evaluated 5 ENDS attributes: relative harm; effectiveness for helping smokers quit; nicotine strength; flavor; and price. We asked participants to choose among their own cigarettes, 2 ENDS products whose attributes varied across tasks, or none. We analyzed ENDS preferences using multinomial, nested, and mixed logit regressions.

Results: Smokers preferred ENDS that are less harmful than cigarettes, are effective in helping smokers quit, are lower priced, and are not menthol-flavored. The marginal willingness to pay for an ENDS product was $8.40 when less harmful than cigarettes, $4.13 when of unknown effectiveness in helping quitting ($13.90 when effective), and $3.37 when ENDS are not menthol-flavored. Furthermore, the overall flavor preference is driven by tobacco smokers, not by menthol cigarette smokers who do prefer menthol-flavored ENDS.

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Human Subjects Approval Statement

This study was approved by the Georgia State University Institutional Review Board.

Conflict of Interest Disclosure Statement

The authors have no conflicts of interest to disclose.

Conclusions: Policies that affect perceptions of ENDS effectiveness in promoting cessation and their relative harm may alter smokers' ENDS preferences. Regulating flavors and price also may influence adult smokers' ENDS preference.

Keywords

e-cigarettes; vaping; preference; attributes; discrete choice experiment

Regulation of electronic nicotine delivery systems (ENDS) is challenging given that ENDS as alternative tobacco products hold the potential to benefit smokers if they are indeed less harmful than cigarettes and smokers use them to quit smoking, versus the popularity of ENDS among youth and young adults who are attracted as new tobacco users.[1] The US Food and Drug Administration (FDA), the agency tasked with regulating ENDS as a tobacco product, recognizes that tobacco products exist along a continuum of risk and that it is necessary to base regulatory decisions on research that sheds light on how regulatory actions influence product choices and the health risks in the population based on these choices.[1,2] With ENDS, and possibly other new tobacco products, such as heated tobacco, that offer potential harm reduction benefits to smokers, regulators face an imposing challenge. They must weigh the potential benefits of reducing the harms associated with smoking by encouraging switching from cigarettes to a less harmful product, against the risk of increased youth adoption of the new products.[2] A new paradigm is needed to understand how consumers react to ENDS, particularly about which product characteristics may motivate adult smokers to switch to ENDS.[4]

For adult smokers who would like to quit, whether ENDS products help with quitting is naturally an important determinant of use. According to the 2013–2014 Population Assessment of Tobacco and Health (PATH) survey, ENDS products were among the frequent methods used by smokers to quit.[5] However, the evidence on whether ENDS are effective in helping cessation is conflicting. Whereas many longitudinal and review studies suggest that smokers who use ENDS are not more likely, and perhaps even less likely to quit smoking,[6,7] other studies draw the opposite conclusion that smokers who initiate or use ENDS are more likely to quit.[9–12] One randomized trial concluded that when accompanied by behavioral support and under advantageous conditions, ENDS are more effective for smoking cessation than nicotine-replacement therapy, which shows the promising effectiveness of ENDS in helping smokers quit.[13]

A report by National Academies of Sciences, Engineering, and Medicine (NASEM) has concluded that ENDS pose fewer harms to individual smokers than cigarettes.[1] However, beliefs and perceptions of the relative harms of ENDS compared to cigarettes may deviate from the scientific evidence. Although generally ENDS are perceived to be less harmful than cigarettes by the public, a growing proportion of US adults believe ENDS to be as harmful or more harmful than cigarettes over time.[14,15] Many US adults also wrongly believe that nicotine is the primary disease-causing chemical constituent,[16] and thus, may misperceive the harms of ENDS. News articles also have mentioned the potential benefits of ENDS less often than their potential harm or risk.[17] Therefore, perceptions regarding the relative harm

of ENDS may play a significant role in smokers' transitions from one tobacco product to another.

Furthermore, ENDS can be used with various levels of nicotine. E-liquid brands commonly offer a variety of nicotine strength, such as low, medium, and high.[1,2] It is unclear how the nicotine strength of ENDS may influence smokers' choice of tobacco product. It is important to understand whether nicotine strength is a factor that motivates smokers to try ENDS.

Another attribute that distinguishes ENDS from combustible cigarettes is characterizing flavor.[1,2] Unlike cigarettes that are available in tobacco or menthol flavors only, ENDS provide a wide selection of flavors such as sweet, fruit, and others, with nearly unlimited combinations.[18] Although studies show that flavors promote uptake among youth and young adults,[19,20] the FDA and other stakeholders also recognize that they may be an important feature for leading smokers to switch to ENDS.[2,21] However, several studies show that adult smokers in the US may prefer tobacco flavor to other flavors.[22,23] Therefore, whereas flavors other than tobacco are appealing to youth, whether the abundance of ENDS flavors encourage older adult smokers to switch to ENDS is unknown.[4]

Many ENDS and cigarette attributes are subject to FDA regulation, such as characterizing flavors and nicotine strength.[2] The FDA also oversees warning labels and product packaging that may shape the risk and harm perceptions of tobacco products. In light of evidence regarding the surge of ENDS use among young people,[24] the US Surgeon General declared a vaping epidemic in December 2018.[25,26] In the near future, there will be growing calls for tighter regulation over ENDS production, sales, and consumption. To evaluate the overall regulatory impacts beyond the youth and young adult populations, it is critical to understand how established smokers are influenced by ENDS attributes, thereby shedding light on the consequences of proposed and potential federal and local tobacco regulation.

This study used a Web-based discrete choice experiment (DCE) conducted among adult smokers to examine the effects of 5 important ENDS attributes on smokers' product preferences: relative harm of ENDS compared with cigarettes, cessation effectiveness; nicotine strength; flavor; and price. There were several goals of this study. First, we sought to inform policymakers about the anticipated effects of potential regulations of ENDS. As described, the potential effects of relative harm, nicotine strength, and flavor on stated preference (use) will generate direct evidence to inform FDA regulation. Price, as one of the experimental attributes, allowed us to estimate marginal willingness-to-pay (WTP) for non-price attributes and to provide a standardized measure through which to compare our results with prior studies. Another motivation for characterizing the price sensitivity of smokers regarding ENDS use was that many state and local governments in the US had considered imposing taxes on ENDS, with its consequences yet to be assessed. Second, the perceived effectiveness of ENDS to help people quit, although being an important factor for switching, was rarely evaluated jointly with multiple attributes in a DCE setting. Our study evaluated the desirability of ENDS under different assumptions about the effectiveness of ENDS as a cessation aid. We further compared the importance of this attribute with the importance of other attributes. Third, this study added to the current debate on whether nicotine

concentration or flavors influence adult smokers' ENDS preferences, which is especially important to understand given the importance of these attributes as determinants of ENDS use.

METHODS

Discrete Choice Experiment

The discrete choice experiment (DCE) is a stated preference technique that has been used increasingly to examine preferences for tobacco products, including ENDS.[27] DCEs are usually conducted using an online survey by presenting participants with a series of choices among different products.[23] During the process, DCE elicits consumers' preferences as a function of product attributes and their marginal WTP for these attributes. Because many tobacco attributes are directly or indirectly subject to federal and local regulation, DCE may help inform policymakers about the potential consequences of regulatory actions. For example, nicotine concentration/content and flavors are under the FDA's regulatory authority, as are warning messages and advertising that may shape how the public perceives and characterizes the risks of a certain product.[1,2]

DCE Design and Attributes

We used a "labeled" DCE design and asked participants to choose among 3 options (Appendix 1): combustible cigarettes, 2 alternative vape pens to represent ENDS, and none of the above. Among these 3 options, combustible cigarettes and none of the above were opt-out options that did not vary within participant. To make choices more closely reflect real-world decisions, we gave the cigarette option the same characteristics as the cigarette product that participants self-reported currently smoking. Therefore, only the 2 ENDS products were generated by the DCE design. We adopted a labeled design, using generic label vape pens A and B, presented with their own cigarettes.[28] The design of the DCE and the selection of the choice sets were conducted using SAS JMP11 using a D-optimal design.

The number of choice sets needed to identify the effects of attributes on ENDS preference among smokers depends on the number of attributes and their levels. Based on the existing literature,[1,4] we identified 5 ENDS attributes that may affect smokers' choice of ENDS products and their transition from cigarettes to ENDS (Table 1): relative harm compared with cigarettes, effectiveness with smoking cessation, nicotine strength, flavor, and price. We determined the levels for each of the 5 attributes based on a search of the literature and available options. Table 1 provides the levels of each attribute.

Because we offered one 2-level, 3 3-level, and one 4-level attributes, this design led to 216 ($2 \times 27 \times 4$) possible hypothetical products. As 2 alternative hypothetical products were needed to identify the effects of attributes on ENDS preference, the full factorial design rose to 23,220 ($216 \times 215 \div 2$) potential combinations. We used SAS JMP 11 and a D-optimal design to generate efficient partial choice profiles that reduce the number of choice sets to 60, which were further divided into 5 versions, each containing 12 choice sets.[29] The number of choice sets per participant was selected to be <16, the recommended maximum number of choice sets to prevent respondent fatigue.[30,31]

Randomization to Incentive Compatible Choices

We further introduced a reward mechanism to mitigate an acknowledged limitation of stated-preference approaches, namely that hypothetical actions may differ from real-world behavior (ie, hypothetical bias).[32] Experimental economists have long believed that making choices "incentive compatible," that is, compensating respondents for revealing their true preferences, are more valid than hypothetical choices.[32] However, studies have found mixed evidence on the divergence between hypothetical versus real decisions in experimental tasks.[33] In our study, we randomly assigned half of the participants to make incentive-compatible decisions, in which they were informed that we would select at random one respondent who would receive $100 worth of the product they choose for a randomly selected choice (question) or cash (Appendix 2). This is known as a "potentially real" choice, as opposed to a real choice in which all participants would receive one of their stated choices. The selected person actually received $100 cash. Thus, participants in the incentive-compatibility group maximized their well-being by selecting the products they really prefer. Our approach capitalized on the advantages of the DCE method while minimizing one of its major limitations using a novel elicitation approach.

Sample

From August through October 2017, we recruited through Gfk KnowledgePanel 1211 US adult smokers aged 18+ who had smoked at least 100 cigarettes in their lifetime and were either dual users of ENDS, or if they were not currently using ENDS, they reported not being completely certain that they would not use ENDS in the future. We dropped 57 persons whose self-reported cigarette prices are out of a plausible price range (lower than 2 dollars or higher than 30 dollars per pack). The final analytical sample consisted of 1154 participants, a sample size that exceeds what the DCE design calls for to detect the effects of attributes on preference.[34] Only 15 participants (1.3%) chose none of the products in all choices.

Data Analysis

Multinomial, nested, and mixed logit models.—Following previous DCE studies,[27] we employed 3 approaches to estimate the effects of the 5 attributes on ENDS preferences: multinomial logit, nested logit, and mixed (random parameter) models. All models also controlled for individual-level socio-demographic characteristics, including gender, age, marital status (married or not), race/ethnicity (white non-Hispanic, non-white and non-Hispanic, and Hispanic), household income (<$20,000; $20,000-$39,999; $40,000-$59,999; $60,000-$99,999; and ≥ $100,000), highest educational attainment (< high school, high school diploma, some college or Associate's degree; and Bachelor's Degree or higher), and tobacco use status measured by indicators for currently smoking cigarettes daily, currently using ENDS, and any past use of ENDS products, even one or 2 times. We also controlled for whether the participant was randomized to the incentive-compatibility condition. Standard errors were clustered at the individual level to account for correlation among choices made by the same individual. The regressions were weighted to represent the US adult smoker population.

The 3 logit models listed above have been used widely in analyzing choice data, with different assumptions about error structures.[32] Conditional logit is the benchmark model for analyzing DCEs, which is an extension of the multinomial logit models in the context of choice behavior. Nested logit regression model decision trees or decision-making steps, with the first step choosing between the "opt-out" options (cigarettes or none of the above) and in the second step, which is conditional on not opting out, choosing between the 2 hypothetical ENDS products. Both methods can be expressed using the following equation for individual *i* and alternative *j* of an attribute:

$$U_{ij} = \alpha_1 Harm + \alpha_2 Flavor + \alpha_3 Nicotine + \alpha_4 Price + \alpha_5 Effectiveness + \beta X_i + \varepsilon_{ij}$$

where the 5 attribute variables are alternative-specific (ij) while socio-demographic and tobacco use variables (X) are individual-specific (i). Marginal WTP is measured as $-\alpha_*/\alpha_4$, where* represents a number corresponding to one of the other coefficients. For example, the marginal WTP for reduced harm of ENDS would be equal to $-\alpha_1/\alpha_4$. One potential limitation of conditional and nested logit models is that they rely on the independence of irrelevant alternatives (IIA) assumption: the choice between 2 alternatives is independent of a third alternative.[35] Conducting likelihood-ratio tests can detect this problem. In this aspect, mixed logit has a clear advantage over conditional or nested logit models since it is robust to violations of the IIA assumption.[35] In addition, mixed logit models take account of individual heterogeneity and thus will produce consistent estimates even when unobserved individual characteristics influence choice behaviors.[36] The following modified equation was used to estimate the mixed logit model:

$$U_{ij} = \alpha_{1i} Harm + \alpha_{2i} Flavor + \alpha_{3i} Nicotine + \alpha_{4i} Price + \alpha_{5i} Effectiveness + \beta X_i + \varepsilon_{ij}$$

We estimated 2 alternative specifications by coding the attribute variables. The first specification used dummies to measure ENDS' harm relative to cigarettes (a dummy for "less harmful to health than cigarettes," with no information about relative harm as reference), flavor (fruit/candy/sweet/other flavors, menthol, with tobacco as reference), and ENDS' effectiveness for helping people quit (effective, unknown, with not effective as reference), and treated nicotine strength (1- Low (1–12 mg), 2- Medium (13–17 mg), 3- High (18 mg or higher)), with None (0 mg) as reference) and price ($3, $5, and $7) as ordered or continuous variables. The second specification explored the nonlinearity of all attribute levels and coded the levels of nicotine strength and price into dummies as well.

Assessment of incentive compatibility.—We tested the difference in socio-demographic characteristics between the 2 groups by the randomized incentive-compatibility condition, and results suggested that these characteristics are similar for the 2 groups. We also examined the associations between randomization and the survey duration, which indicated that being randomized into the incentive condition was associated with spending more time on answering the survey. In addition, among participants who were randomized into the incentive compatibility condition, only 0.9% selected none of the above products for all 12 choices, whereas this percentage was 1.8% among those who did not see

the incentive. These findings provide a rationale to include randomization to the incentive compatibility condition as a factor to predict choices.

RESULTS

Table 2 shows the weighted summary statistics of the analytical sample, including age, gender, household income, educational attainment, race/ethnicity, and marital status. Among cigarette smokers who were not ENDS rejecters, 76% were daily smokers, 77% were ENDS ever users, and 47% were current dual users of both ENDS and cigarettes. 51% of the participants were randomized into the condition of seeing the incentive.

Table 3 presents the choice modeling results estimated using multinomial, nested, and mixed logit regressions. The results are mostly similar across the different logit models with different assumptions of the error structure. First, the coefficients of alternative-specific constants are negative and statistically significant, suggesting that smokers prefer cigarettes to ENDS or none of the products. Second, higher ENDS refill prices significantly reduced the probability of choosing the product.

The coefficients of non-price attributes suggest that an ENDS product that is less harmful to health than cigarettes, compared with no such information given (ie, left blank), was associated with a higher probability of choosing the ENDS product. Compared with an ENDS product that is not effective in helping people quit, an ENDS product that is effective or with an unknown effectiveness was associated with a higher probability of choosing the product.

Compared with tobacco flavor, menthol flavor significantly reduced the probability of choosing ENDS. Mixed logit (random parameter logit) results indicate that fruit/candy/ sweet/ other flavors, compared with a tobacco flavor, also significantly reduces the probability of choosing ENDS. However, this effect is not statistically significant in multinomial or nested logit regressions. In addition, to improve understanding of flavor preference, we conducted additional analyses stratified by current use of menthol cigarettes (results can be shared by request). Although the overall results suggest that smokers do not prefer menthol-flavored ENDS, stratified analyses indicate that this is driven by smokers of tobacco-flavored cigarettes and that smokers of menthol-flavored cigarettes do prefer menthol-flavored ENDS.

In regards to nicotine strength, nested logit regressions show that higher nicotine strength reduces the probability of choosing the ENDS product, but this effect is not statistically significant in multinomial or random parameter logit regressions. To summarize, smokers who are at least minimally open to trying ENDS prefer ENDS products that are less harmful to health than cigarettes, effective in helping people to quit, and have a lower refill price, and do not prefer menthol-flavored products and ones not effective in helping cessation.

The mixed logit results further indicate that the standard deviations for the coefficients of harm, other flavors, and nicotine strength are relatively large compared to the mean, suggesting heterogeneity in smokers' preferences. In addition, the nested logit results suggest several socio-demographic characteristics and tobacco use status are associated with

choosing ENDS over opt-out options (cigarettes or none of the above). These factors include currently using ENDS, non-daily smoking, and being non-white, non-Hispanic.

In Table 4, we present the marginal WTP estimates for non-price attributes using coefficients from the multinomial model, which is commonly used to estimate marginal WTP.[37] The marginal WTP for an ENDS product that is less harmful to health than cigarettes is $8.40. The marginal WTP for an ENDS product with unknown effectiveness in helping cessation is $4.13, whereas for an ENDS product that is effective in helping cessation, the marginal WTP is $13.90. Marginal WTP for a tobacco flavor over a menthol flavor is $3.37. For smokers who are not rejecters of ENDS, a product that is effective in helping people to quit has the greatest impact in choosing ENDS.

When comparing the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) across models in Table 3, these statistics suggest that the nested logit regression model was the preferred model among the 3. Likelihood-ratio and Hausman-McFadden tests rejected that the IIA assumption held, suggesting that the nested logit is likely valid. We also conducted analyses using an alternative specification where all attribute levels were dichotomized (eg, refillable prices at $5 or $7, with $3 as the omitted category). The results for nested and multinomial logit models are presented in Appendix 3. Results for harm, effectiveness in helping cessation, and flavor were very similar to the benchmark specification presented in Table 3. We also conducted multinomial analyses using stratified samples by whether smokers currently also used ENDS (ie, dual use), which are presented in Appendix 4. Results pertaining to harm and effectiveness in helping cessation for both groups were similar to those shown in Table 3. The stratified analyses further illustrate that dual users' preference for flavors did not significantly differ, whereas exclusive smokers did not prefer menthol flavored ENDS. Furthermore, AICs and BICs indicated that models treating nicotine strength and price as ordered or continuous (Table 3) fit data better than models treating them as dichotomous variables (Appendix 3).

DISCUSSION

We conducted a DCE among smokers who were not rejecters of ENDS. Our findings suggest that this population preferred ENDS that are less harmful to health than cigarettes, that are effective in helping people to quit smoking, and that have a lower refill price. They did not prefer products that are menthol flavored.

The attribute that had the most pronounced effect on choosing ENDS was its effectiveness in helping people to quit smoking. This finding is consistent with the existing evidence that using ENDS to reduce withdrawal symptoms or to help with quitting are the most commonly reported reasons for use.[1] Smokers were willing to pay $13.90 for an ENDS product that was identified as effective in helping people to quit. Interestingly, we also found that smokers were more likely to choose ENDS products with an unknown cessation aid effectiveness, compared with a product that was identified as ineffective, and were willing to pay $4.13 for this attribute. There are several implications of these findings. First, the effectiveness of ENDS as a cessation aid perhaps is the most important factor that influences whether smokers will try or continue using ENDS. Second, given that many smokers use

ENDS to help them quit, even without conclusive scientific evidence on its effectiveness, consumers may still have an interest to try. Policymakers may take this into account when considering regulation. If ENDS' effectiveness in aiding quitting is the single most important incentive for smokers to switch, more stringent ENDS regulations affecting other attributes may still achieve an overall net public health benefit by preventing initiation while not eliminating smokers' incentive to switch.

Adult smokers also valued ENDS as being a less harmful product than cigarettes and were willing to pay $8.40 for the reduced harm. In general, people perceived ENDS to be less harmful, indicating that this attribute would incentivize smokers to switch.[1] However, growing evidence suggests that the risk and harm perceptions of ENDS have been shifting more negative.[14] It is unclear what forces have driven this change, although the misperception of nicotine harm and more negative reports of ENDS on news media may have contributed.[17]

Furthermore, the FDA has required all ENDS products and advertisements to carry an addiction warning to convey the message that the product contains nicotine and nicotine is an addictive chemical.[2] Existing evidence shows that the FDA warning unlikely impacts the risk perception of adult smokers, particularly when they are placed in advertisements.[38–41] Therefore, the FDA warning may prevent ENDS initiation among non-tobacco users while not negatively affecting adult smokers' incentive to switch. However, as several studies present, some ENDS brands, notably MarkTen, carry voluntary warnings that describe multiple harms of nicotine, which may cast a negative light on ENDS.[42,43] Another potential policy option for the FDA to consider is to design warning messages that convey the relative harms of ENDS compared to cigarettes, though this would require more evidence on ENDS harms and appropriate communication strategies to ensure statements on relative harm information are accurately conveyed and understood as intended by the consumer.

With respect to flavors, we found that adult smokers were willing to pay $3.37 to have tobacco over menthol and other flavors in ENDS. This finding is consistent with the existing evidence that adult smokers prefer tobacco flavors in North America.[22,23] We also conducted additional analyses and showed that menthol cigarette smokers preferred menthol flavored ENDS, whereas other smokers did not. These findings indicated that smokers prefer ENDS flavors that are same with their cigarette flavors and that there is heterogeneity in smokers' preference for ENDS flavors as a result. Two DCE studies also showed the heterogeneity in flavor preference. One study indicated that young adult smokers prefer many flavors to tobacco flavor.[21] The other study found a similar heterogeneity by age and showed that, whereas a cigarette menthol ban would lead to more switching from cigarettes to ENDS, banning flavors other than tobacco in both products may lead to increased cigarette smoking among adults.[23] Nevertheless, flavors other than tobacco, particularly fruit/sweet/candy and other flavors, are a significant factor for youth and young adults to try ENDS.[4,19] As the sweet / fruity flavors are more appealing for young people and may not be preferred by adult smokers, regulation banning the sale of certain flavored ENDS, particularly fruity or sweet ones, while keeping the relatively more appealing flavor profile of ENDS than cigarettes may achieve public health benefits.[19]

In this study, we did not find consistent evidence of smokers' preferences for nicotine concentration in ENDS, which differs from what prior studies have reported.[1,4] A systematic review suggested that smokers prefer medium and high nicotine ENDS.[4,22] Future studies may explore the heterogeneity in the preference of nicotine strength.[22]

As with many prior studies, we found that smokers were sensitive to ENDS prices.[21,23,37,43,44] The law of demand drives consumers' choices between ENDS and cigarettes. Higher refill prices of ENDS reduced the probability of choosing ENDS. Some localities in the US have implemented ENDS excise taxes, such as Chicago.[45] However, to encourage smokers to quit, a differential tax rate that favors ENDS (ie, lower taxes on ENDS than cigarettes) while keeping ENDS price high enough to deter youth initiation may benefit public health.[46,47] Furthermore, if consumers prefer refillable devices, there is a fixed amount of initial investment on a starter kit, which can be expensive initially even if less expensive in the long run. Making these devices more affordable to smokers also may encourage them to switch.

Finally, we randomized half of the participants and created a financial incentive aimed at reducing the hypothetical bias in stated preference. We found that participants randomized into the incentive condition spent more time on answering the survey and were less likely to choose none of the products. Although the randomization did not significantly increase the likelihood that a smoker chooses ENDS, this certainly can imply that regardless of the randomization, all smoker participants in our experiment had a strong preference for cigarettes.

There are several limitations of this study. DCE is a stated preference technique that may not capture all real-world behaviors.[35] In addition, although existing studies show substantial heterogeneity in ENDS preference by smokers' age and sociodemographic characteristics, in this study, we did not explore the above heterogeneity.[1] In future work, we will use Latent Class Analysis (LCA) to study heterogeneity in preferences and conduct policy simulations of potential regulations based on those results.[35,37] Finally, whereas the level of nicotine contained in cigarettes and the level of nicotine concentration in ENDS may not be directly comparable, it is possible that some smokers mistakenly considered ENDS with high nicotine concentration to deliver more nicotine than a cigarette, and therefore, did not choose ENDS with a high nicotine concentration.

Nonetheless, this DCE study provides important evidence on adult smokers' preference for ENDS attributes. Given that the US ENDS market has been rapidly evolving with newly invented products, such as nicotine salt-based products JUUL and Suorin Drop,[48–51] future studies are needed to understand consumers' preference for ENDS attributes of these increasingly popular products. Future studies may also apply DCEs to understand consumers' preferences for emerging tobacco products in the global market.

IMPLICATIONS FOR TOBACCO REGULATION

ENDS effectiveness in promoting smoking cessation will increase smokers' preference for ENDS. Policies that increase the perceived harmfulness of ENDS, increase ENDS prices,

and decrease the availability of one's preferred tobacco flavor in ENDS will decrease adult smokers' preference for ENDS.

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Appendix 1: An Example of DCE Design

If you were choosing between the following scenarios and these were your only options, which would you choose?

	Cigarettes	Vape Pen A	Vape Pen B
Less harmful to health than cigarettes		Yes	Yes
Effective for helping people quit?		Unknown	Unknown
Nicotine strength	12 mg per stick	High (18 mg or higher)	None (0 mg)
Flavor	Menthol	Tobacco	Tobacco
Price	Price per pack: $15.00	Starter Kit: $30 Refill Price: $3	Starter Kit: $30 Refill Price: $3

Select one answer only

- Cigarettes
- Vape Pen A
- Vape Pen B
- None of the Above

Appendix 2: Incentive Compatible Choices

At the end of this survey, we will select one person and one question at random. The selected person will actually receive $100 worth of the product they chose in the selected question. You should therefore answer these questions truthfully, so that you are awarded your preferred option if you are selected.

For example, if you are selected as the winner and prefer the cigarette product over the vaping products in the selected question, then you would actually receive $100 of cigarettes. We reserve the right to provide $100 in cash instead. Please click here for official rules.

Appendix 3: ENDS Choices among Cigarette Smokers (N = 55,012)

Models	Nested Logit	Multinomial Logit
Parameters	**Coefficient (SE)**	**Coefficient (SE)**
Vape pen 1: ASC	−0.928 *	−1.53 ***
	(0.382)	(0.391)
Vape pen 2: ASC	−1.056 **	−1.583 **

Models	Nested Logit	Multinomial Logit
Parameters	**Coefficient (SE)**	**Coefficient (SE)**
	(0.385)	(0.594)
None of the above: ASC	−2.177	−1.797**
	(2.617)	(0.59)
Non-price attribute 1: Less harmful to health than cigarettes (Blank as ref.)		
Yes	0.36***	0.634***
	(0.045)	(0.063)
Non-price attribute 2: Effective for helping people quit (Not effective as ref.)		
Unknown	0.241***	0.28***
	(0.05)	(0.071)
Effective	0.615***	1.07***
	(0.081)	(0.081)
Non-price attribute 3: Flavor (Tobacco as ref.)		
Menthol	−0.185***	−0.284**
	(0.058)	(0.095)
Fruit/candy/sweet/other	−0.012	−0.009
	(0.05)	(0.103)
Non-price attribute 4: Nicotine Strength (None as ref.)		
Low	0.07	0.094
	(0.051)	(0.1)
Medium	−0.003	0.017
	(0.054)	(0.114)
High	−0.126*	−0.141
	(0.05)	(0.12)
Price attribute: ($3 as ref.)		
Price:$5	−0.12**	−0.277***
	(0.042)	(0.079)
Price:$7	−0.337***	−0.495***
	(0.049)	(0.088)
AIC	26699	26716
BIC	26975	27260
Log likelihood	−13318	−13297

*
p < .05,
**
p < .01,
***
p < .001

Note.

ASC = Alternative-specific constant.

Clustered standard errors adjusting for correlations within choices by the same individuals are in parentheses. Standard deviations of random coefficients are in brackets.

Appendix 4: ENDS Choices among Cigarette Smokers, Multinomial Logit Regressions

Models	Dual users (N=23,980)	Exclusive smokers (N=31,032)
Parameters	**Coefficient (SE)**	**Coefficient (SE)**
Vape pen 1: ASC	−1.024 *	−1.53 ***
	(0.495)	(0.391)
Vape pen 2: ASC	−1.432 *	−1.583 **
	(0.725)	(0.594)
None of the above: ASC	−2.947 ***	−1.797 **
	(0.737)	(0.59)
Non-price attribute 1: Less harmful to health than cigarettes (Blank as ref.)		
Yes	0.643 ***	0.646 ***
	(0.085)	(0.091)
Non-price attribute 2: Effective for helping people quit (Not effective as ref.)		
Unknown	0.235 **	0.352 **
	(0.089)	(0.113)
Effective	0.875 ***	1.324 ***
	(0.105)	(0.12)
Non-price attribute 3: Flavor (Tobacco as ref.)		
Menthol	−0.161	−0.53 ***
	(0.136)	(0.127)
Fruit/candy/sweet/other	0.126	−0.223
	(0.156)	(0.129)
Non-price attribute 4: Nicotine Strength (None as ref.)		
Low	0.179	0.02
	(0.145)	(0.126)
Medium	0.109	−0.098
	(0.161)	(0.156)
High	−0.075	−0.271
	(0.162)	(0.182)
Price attribute: ($3 as ref.)		
Price:$5	−0.266 *	−0.253 *
	(0.109)	(0.115)
Price:$7	−0.575 ***	−0.401 **
	(0.111)	(0.136)
AIC	13381	12741
BIC	13826	13225
Log likelihood	−6636	−6312

* p < .05,
** p < .01,
*** p < .001

Note.

ASC = Alternative-specific constant.

Clustered standard errors adjusting for correlations within choices by the same individuals are in parentheses. Standard deviations of random coefficients are in brackets.

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Table 1

Discrete Choice Experiment (DCE) Attributes and Levels

	Cigarettes[a]	Vape pen
Less harmful to health than cigarettes		Yes [left blank]
Effective for helping people quit		Effective Not effective Unknown
Nicotine strength	12 mg per stick	None (0 mg) Low (1–12 mg) Medium (13–17 mg) High (18 mg or higher)
Flavor	Tobacco[b] Menthol[b]	Tobacco Menthol Fruit/candy/sweet/other flavors
Price	Price per pack[b]	Starter Kit: $30[c] Refill Price: $3 $5 $7

Note.

[a]: Cigarettes are taken as an opt-out option that does not vary within the same individuals.

[b]: Self-reported flavor (menthol or tobacco) and cigarette prices per pack.

[c]: Throughout the experiment, starter kit price is fixed at $30.

Table 2

Weighted Summary Statistics (N = 1154)

Variables	Mean (SD) or Percent (%)
Age	41.3
	(14.2)
Household income	
< $20,000	25.7%
$20,000 to $39,999	24.6%
$40,000 to $59,999	15.8%
$60,000 to $99,999	17.9%
$100,000 or more	16.1%
Educational attainment	
< high school	21.8%
High School diploma	32.9%
Some college or Associate's degree	32.3%
Bachelor's Degree or more	13%
Race/Ethnicity	
White, non-Hispanic	61.2%
Non-white, non-Hispanic	23.5%
Hispanic	15.4%
Male gender	46.9%
Married	49.9%
Randomized to incentive compatibility	50.7%
Tobacco use status among smokers	
Ever used ENDS, even one or 2 times	76.7%
Smoke daily	76%
Currently use ENDS	46.7%

Note.

SD = standard deviations

Table 3

ENDS Choices among Cigarettes Smokers (N = 55,012)

Models	Mixed Logit	Nested Logit	Multinomial Logit
Parameters	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
Cigarettes (ref.)			
Vape pen 1: ASC	−2.240***	−1.29***	−2.047***
	(0.507)	(0.383)	(0.387)
Vape pen 2: ASC	−2.412***	−1.408***	−2.107***
	(0.578)	(0.387)	(0.59)
None of the above: ASC	−5.922***	−3.77	−2.473***
	(0.899)	(1.978)	(0.63)
Non-price attribute 1: Less harmful to health than cigarettes (Blank as ref.)			
Yes	0.39*	0.356***	0.652***
	(0.178)	(0.048)	(0.062)
	[2.20]		
Non-price attribute 2: Effective for helping people quit (Not effective as ref.)			
Unknown	0.444***	0.256***	0.32***
	(0.095)	(0.051)	(0.067)
	[0.082]		
Effective	1.371***	0.623***	1.077***
	(0.215)	(0.085)	(0.08)
	[1.438]		
Non-price attribute 3: Flavor (Tobacco as ref.)			
Menthol	−0.518***	−0.172**	−0.262**
	(0.135)	(0.06)	(0.095)
	[0.008]		
Fruit/candy/sweet/other	−0.657***	−0.006	−0.008
	(0.251)	(0.049)	(0.099)
	[2.273]		
Non-price attribute 4: Nicotine Strength			

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Models	Mixed Logit	Nested Logit	Multinomial Logit
Parameters	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
Nicotine Strength	−0.008	−0.042 *	−0.044
	(0.081)	(0.017)	(0.039)
	[0.475]		
Price attribute	−0.149 ***	−0.08 ***	−0.078 ***
	(0.038)	(0.015)	(0.024)
	[0.089]		
AIC	27315	26674	26699
BIC	27627	26923	27216
Log likelihood	−13622	−13309	−13292

* p < .05,

** p < .01,

*** p < .001

Note.

ASC = Alternative-specific constant.

Clustered standard errors adjusting for correlations within choices by the same individuals are in parentheses. Likelihood-ratio test for IIA: (2) = 534.36, p < .01. Hausman-McFadden test for IIA: (28) = 88.52, p < .01. Standard deviations of random coefficients are in brackets. For convergence, the mixed logit regressions only controlled for gender, age, education (< high school vs high school or more), income (<$20,000 vs above), race/ethnicity (white vs non-white) and ever used ENDS.

Table 4

Marginal Willingness to Pay (mWTP) Estimates for ENDS Attributes

Attributes	Reference	mWTP (SE)
Less harmful than cigarettes	Blank	$8.40 (2.79)
Unknown effectiveness for cessation	Not effective for cessation	$4.13 (1.63)
Effective for cessation	Not effective for cessation	$13.90 (1.29)
Tobacco flavor	Menthol flavor	$3.37 (1.73)

Note.

Standard errors were estimated using the delta method.

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