

# The effect of potential electronic nicotine delivery system regulations on nicotine product selection

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## ABSTRACT

**Aims** To estimate the effect of potential regulations of electronic nicotine delivery systems (ENDS) among adult smokers, including increasing taxes, reducing flavor availability and adding warning labels communicating various levels of risk. **Design** We performed a discrete choice experiment (DCE) among a national sample of 1200 adult smokers. We examined heterogeneity in policy responses by age, cigarette quitting interest and current ENDS use. Our experiment overlapped January 2015 by design, providing exogenous variation in cigarette quitting interest from New Year resolutions. **Setting** KnowledgePanel, an online panel of recruited respondents. **Participants** A total of 1200 adult smokers from the United States. **Measurements** Hypothetical purchase choice of cigarettes, nicotine replacement therapy and a disposable ENDS. **Findings** Increasing ENDS prices from \$3 to \$6 was associated with a 13.6 percentage point reduction in ENDS selection ( $P < 0.001$ ). Restricting flavor availability in ENDS to tobacco and menthol was associated with a 2.1 percentage point reduction in ENDS selection ( $P < 0.001$ ). The proposed Food and Drug Administration (FDA) warning label was associated with a 1.1 percentage point reduction in ENDS selection ( $P < 0.05$ ) and the MarkTen warning label with a 5.1 percentage point reduction ( $P < 0.001$ ). We estimated an ENDS price elasticity of  $-1.8$  ( $P < 0.001$ ) among adult smokers. Statistically significant interaction terms ( $P < 0.001$ ) imply that price responsiveness was higher among adult smokers 18–24 years of age, smokers who have vaped over the last month and smokers with above the median quitting interest. Young adult smokers were 3.7 percentage points more likely to choose ENDS when multiple flavors were available than older adults ( $P < 0.001$ ). Young adult smokers and those with above the median cigarette quitting interest were also more likely to reduce cigarette selection and increase ENDS selection in January 2015 ( $P < 0.001$ ), potentially in response to New Year's resolutions to quit smoking. **Conclusions** Increased taxes, a proposed US Food and Drug Administration warning label for electronic nicotine delivery systems and a more severe warning label may discourage adult smokers from switching to electronic nicotine delivery systems. Reducing the availability of flavors may reduce ENDS use by young adult smokers.

**Keywords** Electronic nicotine delivery systems, tobacco use, tobacco regulation.

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## INTRODUCTION

The emergence of electronic nicotine delivery systems (ENDS) is changing the tobacco market-place rapidly. ENDS are vaping devices that deliver nicotine through an aerosol mist and range in disposability, customization and price [1]. Most adult users of ENDS also smoke conventional cigarettes, and rates of attempting to quit smoking using ENDS products are high [2–5]. While sales of e-cigarettes in the United States have increased from \$20 million in 2008 to \$1.5 billion in 2014 [6,7], sales

of cigarettes have fallen gradually by 29.6% from 2004 to 2014 [7].

ENDS may be a harm-reduction strategy for adult smokers [8]. They have been associated with successful smoking reduction, sometimes with greater success than with nicotine replacement therapy (NRT) [5,8–10]. ENDS products are not harmless, as they contain nicotine and low levels of carcinogens [11,12] and have been associated with symptoms such as airway obstruction, increased diastolic blood pressure, increased heart rate, palpitation, cough and throat irritation [13]. However, smokers

switching to ENDS have reported fewer adverse health effects with ENDS use than cigarette use [14]. Policies to encourage smokers who cannot or do not want to stop smoking to switch to ENDS have been proposed as a way to reduce smoking-related disease, death and health inequalities [10].

There has been a world-wide effort to regulate ENDS. As of May 2015, 71 countries regulate ENDS using national/federal legislation. Twenty-six countries have instituted bans against all sales of ENDS, including Argentina, Brazil, Mexico, Greece, Turkey, Saudi Arabia and Thailand. Sixteen countries have minimum legal purchase ages for ENDS, all with minimum ages of 18 years, except South Korea (19 years) and Honduras (21 years). Two countries, South Korea and Togo, tax ENDS [15].

In this paper, we contribute evidence on key questions faced by policymakers considering regulating ENDS by examining purchasing decisions made by adult smokers in the United States. In the United States, ENDS regulations have been evolving slowly. The Food and Drug Administration's Center for Tobacco Products (FDA-CTP) was vested with broad authorities under the 2009 Family Smoking Prevention and Tobacco Control Act (FSPTCA) to regulate tobacco products. The FDA regulates only ENDS marketed as therapeutic [16], but the FDA-CTP is considering a rule to assert its jurisdiction over ENDS and require that ENDS products carry a health warning [17].

Warning labels on conventional cigarettes have differing levels of deterrence based on the design and messages they incorporate [18,19], thus the ultimate choice of labels selected by the FDA-CTP may influence demand for ENDS. Warning labels, in the form of a small text label, have been mandated for cigarette packages in the United States since 1984. Four rotating warning labels are used currently in cigarettes and are displayed in Fig. 1a [20]. The FDA-CTP's current proposed warning label for ENDS is shown in Fig. 1b [17]. Despite no legal requirement to display warning labels on their products, some ENDS manufacturers do so voluntarily. One ENDS manufacturer, Nu Mark (an Altria Company), has included a more stringent warning label [21]. Internationally, graphic designs and more prominent warning labels on cigarettes have been associated with increased impact [18,22], but they are unlikely to be used for ENDS in the United States because they are not currently allowed for other tobacco products [23].

ENDS are currently available in multiple flavors, including menthol, fruit, candy, dessert, alcohol and a variety of novelty flavors [24,25]. In contrast, the 2009 FSPTCA prohibits flavors other than menthol in combustible cigarettes. The prohibition is seen as a way of discouraging smoking initiation and uptake, because younger people are known to prefer flavored versus unflavored nicotine products

[10,26]. Although the FDA-CTP has regulatory authority to restrict the use of flavors in ENDS, no flavor regulation is currently proposed.

One regulation that the ENDS industry has largely avoided is taxes. Only South Korea and Togo currently tax ENDS on a national/federal level [15]. In the United States, whereas the weighted state cigarette excise tax was \$1.28 per pack and federal excise tax \$1.01 per pack in 2013 [27], as of September 2015 only five states and the District of Columbia had enacted ENDS taxes and there is no federal excise tax [28]. Potentially because of the perceived harm reduction properties of ENDS, 12 proposed state tax increases have failed [29]. While the consensus price elasticity estimate for cigarettes is approximately  $-0.4$ , meaning that a 10% price increase results in a 4% decrease in cigarette purchases [30], current research indicates that ENDS price responsiveness may be more elastic. One study found disposable ENDS and reusable ENDS price elasticities at approximately  $-1.2$  and  $-1.9$ , respectively [31]. Cigarettes have been found to be substitute goods for ENDS in one experimental study in adults [32], but another found no consistent relationship in market observation [31].

In order to identify the effects that warning labels, flavor regulations and prices may have on the choice of nicotine-containing products, this study has aimed to simulate the choice of nicotine-containing products with a discrete choice experiment (DCE) design. In a DCE, respondents make hypothetical choices to purchase products and the product attributes are varied to identify consumer preferences over the attributes [33]. By experimentally varying ENDS warning labels, flavors and prices in a series of choice experiments, we aimed to determine preferences and relative importance placed on each of these factors. To analyze useful cigarette quitting interest variation occurring naturally during the year, we also compared choices before and after January 2015. The beginning of the year is associated with a significant rise in quit attempts (attributed to New Year's resolutions) [34], and warning-label responsiveness has been found to be stronger in those intending to quit [35]. Identifying these preferences will help to inform the international discussion of how to regulate ENDS in a manner that neither encourages youths and other non-smokers to start using nicotine products nor discourages current smokers from quitting.

## METHODS

### Data

We performed a discrete choice experiment (DCE) among 1200 adult smokers surveyed through KnowledgePanel [36]. The DCE was completed between December 2014 and January 2015. The goal of our DCE was to study

## A. Current Cigarette Warning Labels

- “SURGEON GENERAL’S WARNING: Smoking Causes Lung Cancer, Heart Disease, Emphysema, and May Complicate Pregnancy”
- “SURGEON GENERAL’S WARNING: Quitting Smoking Now Greatly Reduces Serious Risks to Your Health”
- “SURGEON GENERAL’S WARNING: Smoking by Pregnant Women May Result in Fetal Injury, Premature Birth, and Low Birth Weight”
- “SURGEON GENERAL’S WARNING: Cigarette Smoke Contains Carbon Monoxide.”

## B. Current Proposed Warning Label for ENDS

- “WARNING: This product contains nicotine derived from tobacco. Nicotine is an addictive chemical.”

## C. Warning Labels Used in the Discrete Choice Experiment

1. **None**
2. **FDA:**  
“WARNING: This product contains nicotine derived from tobacco. Nicotine is an addictive chemical.”
3. **Reduced Risk:**  
“WARNING: No tobacco product is safe, but this product presents substantially lower risks to health than smoking cigarettes.”
4. **MarkTen:**  
“WARNING: This product is not a smoking cessation product and has not been tested as such. This product is intended for use by persons of legal age or older, and not by children, women who are pregnant or breast-feeding, or persons with or at risk of heart disease, high blood pressure, diabetes, or taking medicine for depression or asthma. Nicotine is addictive and habit forming, and it is very toxic by inhalation, in contact with the skin, or if swallowed. Nicotine can increase your heart rate and blood pressure and cause dizziness, nausea, and stomach pain. Inhalation of this product may aggravate existing respiratory conditions. Ingestion of the non-vaporized concentrated ingredients in the cartridges can be poisonous. CA Proposition 65 Warning: This product contains nicotine, a chemical known to the state of California to cause birth defects or other reproductive harm.”

**Figure 1** Warning labels. (a) Current cigarette warning labels; (b) current proposed warning label for ENDS; (c) warning labels used in the discrete choice experiment

how adult smokers are influenced to purchase ENDS based on costs, warning labels and flavors. We received Institutional Review Board (IRB) approval from Cornell University and the University of Illinois at Chicago to perform this study.

KnowledgePanel recruits individuals for the panel using address-based sampling. This recruitment includes individuals using only cellphones and individuals without computer/internet access (which KnowledgePanel provides). From among this panel, we identified eligible respondents as having smoked at least 100 cigarettes in

their life-time, using at least one cigarette during the past 30 days and purchasing cigarettes during the past 30 days.

We constructed our DCE using a balanced design (across levels) in accordance with good research practices in performing these types of experiments [37]. This guideline recommends limiting DCE purchasing choice scenarios to eight to 16 in order to avoid undue burden on participants [37]. Therefore, respondents were assigned one of 10 surveys randomly, with each survey containing 12 of 24 possible price/flavor/warning-label choice scenarios. Our DCE has high *D*-efficiency of 98%, compared to

100% that could be accomplished by asking about all 24 possible choices.

Our choice exercises were prefaced with the following: 'if you were shopping for a tobacco/nicotine product and these were your only options, which would you choose?'. Individuals were then presented with three items from which to choose. The first was one pack of the individual's regular cigarettes. The individuals' preferred brand and price per pack was auto-populated from an earlier question, and respondents were reminded of the first Surgeon General's cigarette warning label in Fig. 1a. The second option was nicotine replacement therapy priced at \$6 for a package equivalent to a pack of cigarettes. Finally, the third option was a disposable ENDS, which was referred to as a disposable vaping device in the survey, with varying price (\$3, 6, 9), flavors (regular/menthol OR an expanded set of flavors including 'tobacco, menthol, clove, spice, candy, fruit, chocolate, alcohol, and other sweets'), and one of four warning labels. Individuals could also proceed in the experiment without selecting any of the three options.

The ENDS warning labels used in this experiment are listed in Fig. 1c. The first warning-label option—no warning—represents the current federal warning-label status for ENDS. The second warning-label option is the proposed FDA warning label [17]. The third warning-label option is a modified risk statement that was proposed originally by a smokeless tobacco manufacturer, RJ Reynolds, in 2011 for their products [38], and included more recently in an application for a modified risk tobacco product (MRTP) for snus, a non-vaping smokeless product, by manufacturer Swedish Match [39,40]. Finally, the fourth warning-label option is the warning label on MarkTen e-cigarettes, which was adopted voluntarily by Nu Mark, an Altria Company [21].

The original sample of 1200 respondents was reduced to 1166 respondents without missing information on prior vaping experience, quit interest, cigarette price paid, income and metro status. Each respondent completed 12 simulated choices, providing 13 992 choices, of which 40 were missing and subsequently dropped (including one person missing all 12 choices). Of the 1165 respondents, we identified 145 individuals (12.5%) exhibiting intransitive preferences and excluded them from our primary analysis. A respondent's choices were considered inconsistent if they choose an ENDS in one simulation, but also choose cigarettes in a near-identical simulation, except that ENDS became more attractive due to a lower price or an increase in their flavor availability. We did not consider risk message in deciding inconsistent preferences, except to hold it constant across choices to examine inconsistent preferences in price or flavors, because the risk messages are not necessarily an ordinal ranking. We performed a sensitivity analysis suggesting small effects of excluding non-transitive preference individuals. Our final sample was thus 1020

individuals without missing information and making transitive choices.

Of our sample, 4.1% had never heard of ENDS, 32.3% had heard of them but had not used them and 63.6% had used them at some point in the past. Life-time e-cigarette use among current cigarette smokers was 55.7% in the 2012–13 National Adult Tobacco Survey [41], so our slightly higher estimate of 63.6% may reflect increases in life-time use between 2012 and 2013 and the end of 2014, or life-time use of other types of ENDS devices than e-cigarettes.

Supporting information, Table S1 provides additional descriptive statistics. Of the respondents, 17.5% used an ENDS in the last month, 17.4% had both tried quitting over the past year and used nicotine replacement therapy (NRT) in the last quit attempt and 16.5% had tried quitting using a vaping device. On a scale of 1–10 for cigarette quitting interest (10 being the most interested), the mean response was 5.89. Respondents choose ENDS 13.5% of the time in the DCE; 78.3% of respondents took between 8 and 68 minutes to complete the survey. Respondents were not required to be complete the survey in one sitting, and 5.4% took longer than 24 hours to complete the survey. Approximately half the participants performed the survey in 2014 (47.0%) and the other half in 2015 (53.0%).

### Empirical strategy

We hypothesize that lower prices, higher availability of flavors and less severe warnings (or no warning) would increase the likelihood of purchasing ENDS. To explore this, we estimated the following preliminary equation:

$$\begin{aligned} \text{ENDS PURCHASE}_{ic} = & a + \beta_1 \text{ENDS PRICE}_{ic} + \beta_2 \text{ENDS FLAVOURS}_{ic} \\ & + \beta_3 \text{ENDS WARNING}_{ic} \\ & + X_i + \text{SURVEY CHAR}_i + \varepsilon, \end{aligned} \quad (1)$$

For individual  $i$  making simulated purchasing choice  $c$ ,  $\text{ENDS PURCHASE}_{ic}$  equals 1 if the individual purchases an ENDS, and is a 0 if they purchase either their usual cigarette product or a NRT product. We estimated a linear probability model for the probability of choosing the ENDS option as a function of indicator variables for each price level, flavor and warning message. We controlled for individual socio-economic characteristics (above 24 years of age, gender, race/ethnicity, marriage status, education, income, labor participation, household size, metro area and region), individual tobacco use characteristics (having above the median cigarette quitting interest, having vaped in the past month, having used NRT in last quit attempt, having used a vaping device in last quit attempt) and survey characteristics (if the individual completed the survey in 2015 and survey duration), and the price that individuals indicate usually paying for their preferred pack of cigarettes. Because each respondent provides multiple



observations of their choices under different experimental conditions, we clustered standard errors at the level of individual [42].

In addition to using a linear probability model, we also explored the sensitivity of our results to using a standard logit model and an alternative-specific conditional logit model. The latter approach allowed us to study characteristics of ENDS selection given the choice of two separate alternative products, cigarettes and NRT, rather than grouping these two products together as a non-ENDS selection.

We hypothesized important differences in how individuals respond to prices, flavor availability and warning labels based on age, current use of vaping and cigarette quitting interest. To explore these hypotheses, we expanded equation (1) by interacting each policy variable (price, flavor availability, warning label) with being a young adult aged 18–24 years, using a vaping device in the past month and having above the median cigarette quitting interest. This allowed us to gauge differences in the effect of these policies on different types of adult smokers.

## RESULTS

In Table 1, we provide tabulations of the percent of respondents choosing an ENDS by price, flavor availability and warning label. We stratified these results by age (panel a), cigarette quitting interest (panel b) and vaping over the past month (panel c). We stratified results by these characteristics because of our a priori hypothesis that regulatory policies have differential effects on these groups. In later results, we demonstrate statistically significant interactions between these groups and various regulatory options that justify this stratification.

All analyses show that ENDS prices are related inversely to ENDS selection. Younger adults selected an ENDS 34.4% of the time at a price level of \$3, 16.7% of the time at a price level of \$6 and 8.0% of the time at a price level of \$9. ENDS choices by older adults declined similarly as prices rose, from 18.3% at \$3 to 3.2% at \$9. For individuals with lower cigarette quitting interest, ENDS were chosen 16.6% of the time at a price of \$3 and 2.3% at a price level of \$9. ENDS were chosen more often among individuals at higher cigarette quitting interest, 34.3% at \$3 and 8.5% at a price level of \$9. For individuals that had not used vaping devices in the past month, prices fell from 19.9% at \$3 to 3.6% at \$9, compared to 46.3% and 12.0% for individuals that had used vaping devices over the past month.

In all groups, respondents were least likely to choose ENDS with the MarkTen warning label ( $P < 0.001$ ). Additionally, in all groups, the FDA proposed warning label and modified risk warning label were not associated with reductions in ENDS product selection compared to not having a warning label.

We discovered an interesting heterogeneity in how flavor availability influences purchasing of ENDS products. Increased flavor availability increased ENDS selection, from 17.5 to 21.9% for younger adults ( $P < 0.001$ ), but was not associated with a practically or statistically significant increase for older adults. Similarly, increased flavor availability increased ENDS selection ( $P < 0.001$ ) for individuals who have not used vaping devices in the past month, but was not associated with a statistically significant increase in ENDS selection for individuals who have. Regardless of cigarette quitting interest, both populations increased selection of ENDS products when more flavors were available.

We present linear probability model results for equation (1) on the left of Table 2. We find that increasing price is

**Table 1** (a) Percentage of respondents choosing a disposable vaping device by price, flavors and warning label for respondents aged 18–24 and aged 25 or older.

	Aged 18–24			Aged 25 or older		
	%	95% CI	P	%	95% CI	P
Price						
\$3	34.4			18.3		
\$6	16.7 <sup>***</sup>	(−0.204, −0.150)	0.000	7.2 <sup>***</sup>	(−0.126, −0.094)	0.0000
\$9	8.0 <sup>***</sup>	(−0.291, −0.238)	0.000	3.2 <sup>***</sup>	(−0.166, −0.134)	0.0000
Warning label						
None	22.5			10.6		
FDA	20.3	(−0.054, 0.010)	0.177	10.1	(−0.024, 0.013)	0.575
Reduced risks	20.9	(−0.049, 0.015)	0.304	10.9	(−0.016, 0.021)	0.790
MarkTen	15.1 <sup>***</sup>	(−0.106, −0.042)	0.000	6.8 <sup>***</sup>	(−0.057, −0.020)	0.000
Flavors						
Tobacco/menthol	17.5			9.2		
Many flavors	21.9 <sup>***</sup>	(0.022, 0.067)	0.000	9.9	(−0.007, 0.020)	0.327

**Table 1** (b)Percentage of respondents choosing a disposable vaping device by price, flavors and warning label for respondents having above or below median level of quit interest.

	<i>Quit interest low</i>			<i>Quit interest high</i>		
	%	95% CI	<i>P</i>	%	95% CI	<i>P</i>
Price						
\$3	16.6			34.3		
\$6	5.8 <sup>***</sup>	(−0.124, −0.092)	0.000	17.2 <sup>***</sup>	(−0.196, −0.146)	0.000
\$9	2.3 <sup>***</sup>	(−0.159, −0.128)	0.000	8.5 <sup>***</sup>	(−0.283, −0.233)	0.000
Warning label						
None	9.8			22		
FDA	8.8	(−0.028, 0.009)	0.321	20.5	(−0.045, 0.015)	0.326
Reduced risks	8.8	(−0.028, 0.009)	0.297	22.1	(−0.029, 0.031)	0.957
MarkTen	5.7 <sup>***</sup>	(−0.060, −0.023)	0.000	15.4 <sup>***</sup>	(−0.096, −0.036)	0.000
Flavors						
Tobacco/menthol	7.5			18.6		
Many flavors	9 <sup>*</sup>	(0.003, 0.029)	0.019	21.4 <sup>**</sup>	(0.007, 0.050)	0.009

**Table 1** (c)Percentage of respondents choosing a disposable vaping device by price, flavors and warning label for respondents having used or not used vaping devices in past month.

	<i>Not used vaping devices in past month</i>			<i>Used vaping devices in past month</i>		
	%	95% CI	<i>P</i>	%	95% CI	<i>P</i>
Price						
\$3	19.9			46.3		
\$6	8.1 <sup>***</sup>	(−0.132, −0.103)	0.000	23.9 <sup>***</sup>	(−0.268, −0.180)	0.000
\$9	3.6 <sup>***</sup>	(−0.177, −0.148)	0.000	12 <sup>***</sup>	(−0.388, −0.300)	0.000
Warning label						
None	11.9			30.9		
FDA	11.2	(−0.024, 0.010)	0.431	27.3	(−0.089, 0.018)	0.192
Reduced risks	11.6	(−0.019, 0.014)	0.774	29.3	(−0.070, 0.037)	0.550
MarkTen	7.4 <sup>***</sup>	(−0.061, −0.028)	0.000	22.1 <sup>**</sup>	(−0.141, −0.034)	0.001
Flavors						
Tobacco/menthol	9.6			25.9		
Many flavors	11.5 <sup>**</sup>	(0.007, 0.031)	0.002	28.9	(−0.007, 0.068)	0.115

All estimations are for respondents showing transitive behavior. \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ . CI = confidence interval; FDA = Food and Drug Administration.

associated negatively with ENDS selection among adult smokers. They were 13.6 percentage points less likely to choose an ENDS at \$6 compared to \$3 ( $P < 0.001$ ) and 19.4 percentage points less likely to choose an ENDS at \$9 ( $P < 0.001$ ). Greater flavor availability was associated with a 2.1 percentage point increase in ENDS selection ( $P < 0.001$ ). A reduced risk warning label was not associated differentially with ENDS selection compared to no warning label, but the proposed FDA warning label was associated with a 1.1 percentage point reduction in ENDS selection ( $P < 0.05$ ) and the MarkTen warning label associated with a 5.1 percentage point reduction in ENDS selection ( $P < 0.001$ ). The MarkTen warning label has a

larger effect than the FDA proposed warning label ( $P < 0.001$ ). Finally, being aged 18–24 years, having vaped in the past month and having above the median cigarette quitting interest were associated with being more likely to choose an ENDS.

We present results for the interaction model on the right of Table 2. Young adults aged 18–24 years, smokers who have vaped over the last month and smokers with above the median quitting interest were more price-responsive than adult smokers aged 25 years and older. Additionally, young adults were 3.7 percentage points more likely to choose ENDS when multiple flavors were available than older adults ( $P < 0.001$ ). Finally, young adult smokers

Table 2 Linear probability models of choice of disposable vaping devices.

	Coefficient	95% Confidence interval	P-value	Coefficient	95% Confidence interval	P-value
Price: \$6	-0.136***	(-0.154, -0.118)	0.000	-0.074***	(-0.097, -0.052)	0.000
Price: \$9	-0.194***	(-0.215, -0.173)	0.000	-0.086***	(-0.112, -0.060)	0.000
Flavors: many flavors	0.021***	(0.013, 0.029)	0.000	0.001	(-0.008, 0.010)	0.842
Warnings: FDA	-0.011*	(-0.021, -0.001)	0.026	-0.001	(-0.012, 0.010)	0.887
Warnings: reduced risks	-0.004	(-0.013, 0.006)	0.448	-0.001	(-0.012, 0.010)	0.807
Warnings: MarkTen	-0.051***	(-0.064, -0.039)	0.000	-0.024***	(-0.038, -0.010)	0.001
Young adults	0.059	(0.018, 0.100)	0.005	0.103***	(0.044, 0.162)	0.001
Used vaping in last month	0.126***	(0.081, 0.172)	0.000	0.223***	(0.149, 0.297)	0.000
Quit interest above median level	0.090***	(0.059, 0.120)	0.000	0.140***	(0.089, 0.190)	0.000
Interactions						
Price: \$6 × young adults	-	-	-	-0.054**	(-0.093, -0.016)	0.005
Price: \$9 × young adults	-	-	-	-0.093***	(-0.138, -0.049)	0.000
Price: \$6 × used vaping in last month	-	-	-	-0.089**	(-0.146, -0.032)	0.002
Price: \$9 × used vaping in last month	-	-	-	-0.150***	(-0.215, -0.085)	0.000
Price: \$6 × quit interest above median level	-	-	-	-0.056**	(-0.093, -0.020)	0.002
Price: \$9 × quit interest above median level	-	-	-	-0.103***	(-0.146, -0.061)	0.000
Flavors: many flavors × young adults	-	-	-	0.037***	(0.020, 0.055)	0.000
Flavors: many flavors × used vaping in last month	-	-	-	0.002	(-0.021, 0.026)	0.849
Flavors: many flavors × quit interest above median level	-	-	-	0.013	(-0.003, 0.029)	0.123
Warnings: FDA × young adults	-	-	-	-0.011	(-0.034, 0.012)	0.350
Warnings: reduced risks × young adults	-	-	-	-0.015	(-0.037, 0.007)	0.175
Warnings: MarkTen × young adults	-	-	-	-0.029*	(-0.058, -0.001)	0.046
Warnings: FDA × Used vaping in last month	-	-	-	-0.025	(-0.055, 0.005)	0.105
Warnings: reduced risks × used vaping in last month	-	-	-	-0.012	(-0.042, 0.019)	0.454
Warnings: MarkTen × used vaping in last month	-	-	-	-0.035	(-0.076, 0.006)	0.097
Warnings: FDA × quit interest above median level	-	-	-	-0.003	(-0.023, 0.017)	0.752
Warnings: reduced risks × quit interest above median level	-	-	-	0.013	(-0.007, 0.032)	0.212
Warnings: MarkTen × quit interest above median level	-	-	-	-0.022	(-0.048, 0.004)	0.102
Survey completion Characteristics	-	Yes	-	-	Yes	-
Socio-demographic Characteristics	-	Yes	-	-	Yes	-
Tobacco use Characteristics	-	Yes	-	-	Yes	-
Geographic Region/metro	-	Yes	-	-	Yes	-
Observations	-	12 213	-	-	12 213	-
Dep var mean	-	0.13	-	-	0.13	-

Data from a discrete choice experiment (DCE) by UIC, Cornell, GfK. All estimations are for respondents showing transitive behavior. The reference categories for attribute variables are (\$) for price (tobacco/menthol) for flavor and (none) for warning. The reference categories for the electronic nicotine delivery systems (ENDS) price interactions are the differentials for each subgroup at an ENDS price level of \$3. Standard errors are cluster-corrected at the individual level. \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ . FDA = Food and Drug Administration.

were 2.9 percentage points less likely to choose an ENDS product with the MarkTen warning label compared to adult smokers aged 25 years and older ( $P < 0.05$ ).

In the Supporting information, Table S2, we demonstrate that results for equation (1) are substantially similar when we use a logit model and convert the coefficients to marginal effects. We use this model to estimate a price elasticity of  $-1.8$  for the propensity to choose ENDS ( $P < 0.001$ ), which implies that a 10% increase in ENDS prices reduces ENDS selection by 18% for adult smokers.

In Table 3, we explore possible effects of New Year's resolutions to quit or reduce cigarette consumption by comparing responses in December 2014 to January 2015. We find evidence of New Year's resolutions influencing choices in our DCE. We hypothesize that adult smokers with the highest cigarette quitting interest would be most likely to make a New Year's resolution to quit or reduce smoking, and we find that cigarette choices declined by 8.3% from December 2014 to January 2015 for this population ( $P < 0.001$ ). In comparison, there was no statisti-

cally significant change in cigarette consumption for adult smokers with the lowest cigarette quitting interest. Adult smokers with the highest cigarette quitting interest were 24% more likely to choose ENDS in the New Year ( $P < 0.001$ ), suggesting that this may be a preferred substitute product over NRT, which only increased by a statistically insignificant 5.4%.

Table 3 also shows that younger adults may be more likely to make a smoking cessation resolution. The choice of cigarettes declined by 7.6% among younger adults in January 2015 ( $P < 0.001$ ), and was timed with a 29.7% increase in choices of ENDS ( $P < 0.001$ ). We did not observe any statistically significant differences among older adults.

We performed several sensitivity analyses. In unreported results, we found no evidence of order in which warning labels are presented to individuals through the 12 choices as having an independent influence on the choice of ENDS. Similarly, the number of times that individuals had previously viewed a given warning label had no

**Table 3** (a)Percentage of choices by interview year for respondents aged 18–24 and aged 25 or older.

	<i>Aged 18–24</i>				<i>Aged 25 or older</i>			
	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>
One pack of cigarettes	69.3	64.0	−7.6% <sup>***</sup>	0.000	81.5	80.3	−1.5%	0.168
Nicotine replacement therapy	13.7	13.9	1.4%	0.856	9.1	9.9	8.8%	0.240
Disposable vaping device	17.0	22.0	29.7% <sup>***</sup>	0.000	9.4	9.8	4.9%	0.505
Total	100	100			100	100		

**Table 3** (b)Percentage of choices by interview year for respondents having above or below median level of quit interest.

	<i>Quit interest low</i>				<i>Quit interest high</i>			
	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>
One pack of cigarettes	87.7	86.2	−1.7%	0.074	63.6	58.4	−8.3% <sup>***</sup>	0.000
Nicotine replacement therapy	4.7	4.7	−1.4%	0.901	18.6	19.6	5.4%	0.354
Disposable vaping device	7.6	9.1	20.3% <sup>*</sup>	0.023	17.7	22.0	24.0% <sup>***</sup>	0.000
Total	100	100			100	100		

**Table 3** (c)Percentage of choices by interview year for respondents having used or not used vaping devices in past month.

	<i>Not used vaping past month</i>				<i>Used vaping past month</i>			
	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>	<i>2014</i>	<i>2015</i>	<i>Change</i>	<i>P</i>
One pack of cigarettes	80.1	76.0	−5.1% <sup>***</sup>	0.000	65.5	60.3	−8.1% <sup>*</sup>	0.012
Nicotine replacement therapy	10.9	12.0	9.9% <sup>***</sup>	0.091	9.3	9.9	6.1%	0.657
Disposable vaping device	9.0	12.0	33.7% <sup>***</sup>	0.000	25.1	29.9	18.7% <sup>*</sup>	0.015
Total	100	100			100	100		

All estimations are for respondents showing transitive behavior and having started and finished the survey within the same year. <sup>\*</sup> $P < 0.05$ ; <sup>\*\*\*</sup> $P < 0.001$ .



independent effect. We also found that our results are robust to estimating equation (1) using an alternative-specific conditional logit model.

In the Supporting information, Table S3, we re-estimate our regressions including responses from 145 individuals who we excluded previously for having inconsistent preferences. We find that our results for price and flavor availability are attenuated somewhat from Table 3 results, with estimates including non-transitive individuals suggesting a 17.5 percentage point reduction in the likelihood of purchasing ENDS at \$9 compared to \$3, whereas there was a more substantial 19.4 percentage point reduction in the likelihood when non-transitive individuals are excluded. However, our results are substantially similar regardless of including or excluding non-transitive respondents.

## DISCUSSION

In this paper, we contribute evidence on key questions faced by policymakers considering regulating ENDS by examining purchasing decisions made by adult smokers. Regulating these devices is complicated, because consumers are not fully aware of the relative risks of cigarettes versus ENDS and because ENDS have potential value as a harm reduction device.

The MarkTen warning label is associated with less frequent purchasing of ENDS, which is open to several interpretations. The MarkTen warning label is different from other explored warning labels by mentioning that the product is not a smoking cessation product and has not been tested as such, by identifying a group of vulnerable individuals who should not use the product and by containing additional information on how nicotine is addictive and harmful. One interpretation is that the strong response to this warning in our DCE means that individuals might be unaware of these dangers. Another interpretation is that they might be over-reacting and becoming overly pessimistic about ENDS. It is not clear if including the components of the MarkTen warning in the eventual FDA-CTP required warning label would lead to more or less accurate consumer perceptions of the relative risks of ENDS use versus smoking.

In navigating how to regulate the harmful aspects of ENDS effectively while not limiting potential useful applications as harm reduction products, the FDA-CTP and other similar policymaking bodies may find it useful to reduce the appeal of these devices to adolescents. There is suggestive evidence that nicotine may be more harmful to adolescents [43], and adolescents are less likely to use these devices for smoking cessation/reduction purposes than adults [44]. Adolescents are not in our study, but our findings that young adult smokers are influenced by ENDS flavors, whereas older adult smokers are not, suggests that removing flavor availability could have a relatively minor

impact on adult smokers using ENDS (potentially for smoking cessation/reduction) but could have large impacts on the attractiveness of ENDS for adolescents. Therefore, an effective regulatory strategy may be to reduce flavor availability of ENDS to regular and menthol, similar to what has been done with cigarettes [26].

We find evidence that adult smokers are much less likely to purchase ENDS when the price is high, consistent with one other study [31]. Taxing these products would be effective in reducing harms caused by these products, but would also limit their ability to provide harm reduction. A more effective regulatory strategy may be to provide additional information on harms of ENDS in warning labels and limit features more attractive to youth, such as flavors.

One limitation of our study is that we analyzed disposable products rather than non-disposable products. However, we surveyed individuals after completing the DCE on whether the option of a disposable vaping device rather than a refillable vaping device would have changed their choices. Only 9% of respondents said that they would have been 'much more likely' to choose the vaping device if it had been refillable instead of disposable. Current users of vaping devices were much more likely to feel this way (25.3%) compared to non-current users (6.0%). Sixty-three per cent said they would be about as likely or only somewhat more or somewhat less likely to choose a vaping device if it had been refillable. Therefore, this study limitation is mitigated due to the small number of individuals with strong preferences for refillable vaping devices.

A second limitation is that our study is based on survey responses in a DCE rather than on market observations. DCEs and other stated-preference surveys are used widely in economics and marketing [45]. Many researchers conclude that the results of well-designed stated preference surveys are useful for policymaking [46], but others disagree [47]. Our DCE provides evidence of external validity as our disposable ENDS price elasticity of  $-1.8$  is not statistically different from a disposable price elasticity of  $-1.2$  estimated using market data [31]. Further, our results pass a number of internal validity checks [48], such as our coefficients meeting theoretical predictions and testing for non-transitive preferences.

A third limitation is that our study included only current smokers. Our study does not investigate the effect of policies on adults who only vape, for example, or adults who do neither but who may be open to 'experimenting' with vaping. The effect of the product characteristics explored in this study may be different for these populations.

## Declaration of interests

None.

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### Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

**Online Table 1** Analysis Sample Summary Statistics

**Online Table 2** Marginal effects from logit models of choice of disposable vaping devices

**Online Table 3** Linear probability models of choice of disposable vaping devices, including non-transitive respondents