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Which smokers adopt e-cigarettes and at what price? An experimental estimation of price elasticity of demand and factors correlated with e-cigarette adoption

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Abstract

E-cigarette use has surged in recent years. Many of these new users are cigarette smokers. It is unclear whether e-cigarette adoption by smokers will lead to improved public health due to uncertainty about whether e-cigarettes help smokers quit using cigarettes and about whether ongoing dual use reduces exposure to toxins. A third source of uncertainty is whether providing cigarette smokers with sample e-cigarettes increases e-cigarette adoption. To provide insight into this final issue, we follow up with cigarette smokers who left an experimental auction with an e-cigarette, contacting them after two weeks, six weeks, and six months to determine which demographic and smoking-related characteristics predict continued e-cigarette use. We find that smokers who have made a serious quit attempt, have been advised to quit smoking, or have previously tried e-cigarettes are significantly more likely to report continued e-cigarette use. Women and smokers from racial and ethnic minority groups are significantly less likely to use e-cigarettes at follow up, as are those who said they would rather quit than switch to e-cigarettes. We also use experimental auction bids to estimate the price elasticity of demand for e-cigarettes, finding that a 10% increase in price results in a 5.6% reduction in quantity demanded. This suggests e-cigarette demand is less price sensitive than some earlier studies have found. While a tax on e-cigarettes can still be an effective tool for reducing e-cigarette demand, the reduction in demand may be smaller than some earlier studies would suggest.

1. Introduction

E-cigarettes sales have exploded, with revenue growing 60 fold between 2010 and 2016.[1] Whether this is good news from a public health perspective depends on who is adopting e-cigarettes. Because they may be a lower-risk alternative to conventional cigarettes,[2]

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transitioning cigarette smokers to e-cigarettes could be a public health victory. Though evidence that e-cigarettes help smokers quit conventional cigarettes is mixed,[3,4] this has not the promotion of e-cigarettes as a cessation aid.[5,6] There is evidence that dual users of cigarettes and e-cigarettes are more likely to intend to quit smoking and to have attempted to quit,[7] but dual use does not appear to reduce exposure to smoking-related toxins and carcinogens.[8] Most alarmingly, teen nicotine use has grown dramatically as a result of e-cigarettes, reversing a decades-long trend of decreasing use.[9]

From a health policy standpoint, another source of uncertainty is whether providing cigarette smokers with a sample e-cigarette will encourage adoption. The U.S. government's 2016 "deeming" regulation extended the existing ban on providing free samples of tobacco products to e-cigarettes,[10] but anecdotal evidence suggests e-cigarette retailers are providing free and discounted samples.[11] Deeming does allow free e-cigarette samples to be provided with the purchase of another tobacco product. This would allow traditional tobacco companies to promote e-cigarette use, which is particularly relevant given tobacco companies' increased investment in e-cigarettes.[12] Therefore, understanding which smokers are most likely to begin using e-cigarettes when provided with a sample is an important unanswered public health question.

In earlier research, we used experimental auctions to estimate smokers' demand for e-cigarettes.[13] These auctions were not hypothetical; winning bidders purchased e-cigarettes before leaving the study. Because participants faced real and immediate financial consequences, their bids provide a more reliable estimate of the amount they were willing to pay for e-cigarettes than would answers to hypothetical survey questions.[14] We found that smokers with better self-reported health, lower body mass index, and more education were willing to pay more for e-cigarettes.

In a later study, we followed up with auction participants after 2 weeks, 6 weeks, and 6 months.[15] We found that participants who won an e-cigarette in our experimental auction - and therefore took one home from the experiment - were two to three times more likely to be regular e-cigarette users at follow up but were no more likely to have quit smoking. This was true even after controlling for the amount participants were willing to pay for e-cigarettes and for previous e-cigarette use.

In the current study, we focus on auction winners in order to identify which demographic and smoking-related characteristics correlate with continued e-cigarette use. We also estimate price elasticity of demand (PED) for e-cigarettes, a measure of how sensitive e-cigarette demand is to changes in the price of e-cigarettes. Understanding how e-cigarette demand responds to changes in price has important implications for policymakers looking to discourage or encourage e-cigarette use by raising or lowering taxes. It is also useful for policymakers forecasting the amount of revenue that would be collected after a change in e-cigarette taxes.

2. Methods

2.1. Study design

The Institutional Review Board at Susquehanna University approved this study. For a detailed discussion of inclusion criteria and methods, see our earlier work.[13,15] In brief, we recruited 432 current smokers in Selinsgrove, PA, and Buffalo, NY, who were 18 or older, had no major health concerns, and were not regular e-cigarette users. Each smoker received $80 for taking part in the 70-minute study.

Depending on the treatment, subjects viewed no e-cigarette advertisement, a print ad, a video ad, or both. (This was done as part of a separate study looking at the effects of e-cigarette advertisements on cigarette and e-cigarette demand.[13]) Subjects then submitted bids for a single-use e-cigarette, a rechargeable e-cigarette, and a pack of conventional cigarettes in three separate experimental auctions. Specifically, we used the Becker-DeGroot-Marschak (BDM) mechanism where a subject's bid was compared to a randomly drawn price.[16] If the subject's bid was greater than that price, the subject purchased the product, paying the randomly drawn price. Because a subject's bids did not influence the price paid if he or she won, the auction was "demand revealing," meaning a subject could do no better than submit a bid equal to exactly what he or she was willing to pay for the product. After a subject bid in each of the three auctions, one of the auctions was randomly selected to be carried out. We did this so the subject would not need to worry about winning more than one of the products for sale.

To determine whether the effects of winning an e-cigarette changed over time, we called participants two weeks, six weeks, and six months after the auction experiment and asked a series of questions about their smoking behavior, including whether they had begun regularly using e-cigarettes.

2.2. Data analysis

To identify which demographic and smoking-related characteristics were associated with continued e-cigarette use, we use the following random-effects probit model:

$$Prob(Y_{it} = 1) = f(\alpha + \beta' X_i + \eta_i + \varepsilon_{it}), \quad 1)$$

where Y_{it} is an indicator variable equal to 1 if a smoker reported using an e-cigarette occasionally or daily at follow-up call t, a is an intercept term, X_i is a vector of the demographic and smoking-related characteristics summarized in Table 1, β' is the associated coefficient vector, η_i is an individual-specific random effect, and $\mathcal{E}_{it}$ is an error term.

Price elasticity of demand (PED) is a measure of the sensitivity of demand to changes in price. Specifically, it measures the percent change in quantity demanded associated with a one percent change in price. We construct the demand for e-cigarettes by recognizing that at a price equal to the highest bid submitted, only one participant would be willing to buy an e-cigarette, so we assume the quantity demanded at that price would be one. At a price equal to the second-highest bid, the quantity demanded would be two, and so on. Next, we perform an inverse hyperbolic sine (IHS) transformation on bids for e-cigarettes:

$$\tilde{b}_j = \ln\left(b_j + \sqrt{b_j^2 + 1}\right), \quad (2)$$

where b_j is the jth-highest bid for the single-use e-cigarette, and $\tilde{b}_j$ is the jth-highest IHS bid. We use this log transformation because auction bids were skewed to the right. The IHS transformation is similar to the conventional log transformation but does not require removing zero bids. We estimate the relationship between the quantity of e-cigarettes demanded and IHS price using the following linear regression:

$$Q_j = \alpha + \beta\tilde{b}_j + \varepsilon_j, \quad (3)$$

where Q_j is the quantity demanded at the jth-highest bid, and $\mathcal{E}_j$ is an error term. Following Bellmare and Wichman,[17] we estimate PED as

$$\text{PED} = \frac{\hat{\beta}\,\bar{b}}{\bar{Q}\sqrt{\bar{b}^2 + 1}}, \quad (4)$$

where $\hat{\beta}$ is the coefficient estimate from equation (3), $\bar{Q}$ is the average quantity demanded, and $\bar{b}$ is the average bid.

3. Results

Three hundred thirty-six subjects completed at least one of the follow-up calls, 94 of whom won one of the e-cigarettes during the auction experiment. Of these 94 auction winners, 87 answered all relevant questions about demographic and smoking-related characteristics during the auction experiment. Table 1 presents summary statistics.

Table 2 presents the results from the random-effects probit regression described in equation (1). We find that smokers who had made a past serious quit attempt, those who had been advised to quit by a healthcare professional, and those who had used e-cigarettes in the past were significantly more likely to report using e-cigarettes at follow up (by 19, 19, and 13 percentage points, respectively). Women, nonwhite or Hispanic smokers, and those who would rather quit than use e-cigarettes were significantly less likely to report using e-cigarettes at follow up (by 15, 25, and 15 percentage points, respectively). Smokers were 13 percentage points less likely to use e-cigarettes at the six-month follow up than at the baseline two-week follow up. This difference is statistically significant at the 0.01 level.

Estimating PED as described in equation (4), we find that PED for the 94 smokers who won an e-cigarette and completed at least one follow-up call was −0.56 (95% CI [−0.60, −0.53]), suggesting a 10 percent increase in e-cigarette price would lead to a 5.6 percent decrease in quantity of e-cigarettes demanded. As a robustness check, we estimate PED for the 242 smokers who did not win but completed at least one follow-up call. We again find it is −0.56 (95% CI [−0.57, −0.55]). Finally, we estimate PED for smokers who have and have not previously used e-cigarettes. These estimates are −0.57 (95% CI [−0.63, −0.52]) and −0.55 (95% CI [−0.62, −0.48]), respectively.

4. Discussion

The effects of a past quit attempt, being advised to quit, gender, race, and attitudes toward e-cigarettes on e-cigarette adoption are not just statistically significant but are quite large. Considering 45% of auction winners reported using e-cigarettes at at least one follow-up call, it is remarkable, for example, that a previous quit attempt increases the probability of e-cigarette use by 19 percentage points. Smokers who have tried unsuccessfully to quit may see e-cigarettes as a solution. This has potential for harm reduction if these smokers could make a complete switch to e-cigarettes.

Our estimates of PED for e-cigarettes are in line with previous estimates of PED for conventional cigarettes. For example, an exhaustive review by the International Agency for Research on Cancer's found PED estimates for cigarettes cluster between −0.2 and −0.6.[18] By contrast, studies often find e-cigarette demand is highly price sensitive.[19,20,21] Huang et al., for example, using Nielsen scanner data from major U.S. cities, found PED for e-cigarettes ranged from −1.4 to −1.6 depending on the type of device.[22] And Zheng et al., using scanner data from U.S. convenience stores, estimated e-cigarette PED to be −2.8.[23] One reason studies using scanner data find larger PED estimates (in absolute value) may be that scanner data do not capture sales online or in vape shops, which together account for 45% of U.S. e-cigarette sales.[24] If e-cigarette users respond to higher prices in traditional outlets by buying e-cigarettes online, scanner data would incorrectly indicate that the price increase led to a decrease in quantity demanded.

The size of these PED estimates has important policy implications. If e-cigarette demand is highly price sensitive - as several earlier studies suggest - an e-cigarette tax like Minnesota's equal to 95% of wholesale price will have a profound effect on demand. But if e-cigarette demand is less price sensitive - as our estimates and those of Stoklosa et al. and Pesko et al. suggest[25,26] - high taxes will be less effective at reducing e-cigarette use. This is not an argument against taxes. However, policymakers and public health advocates should be aware that a tax of a given size will lead to a smaller reduction in e-cigarette use if demand is less price sensitive than expected.

An important question for future research is the extent to which e-cigarette taxes will affect e-cigarette initiation; the history with cigarettes suggests increases in price have strong effects on youth.[27] Another question is whether bans are more effective than taxes at limiting e-cigarette use. Bans may seem clearly superior if demand is insensitive to tax increases, but city-level bans may simply act as an "inconvenience tax," compelling users to buy their e-cigarettes in a neighboring city. An interesting extension of our research would be to estimate cross-price elasticity of demand. This would allow researchers and policymakers to anticipate how e-cigarette demand would change in response to changes in cigarette prices, or how cigarette demand would change in response to the introduction of taxes on e-cigarettes.

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Table 1.

Summary statistics for those who won an e-cigarette during the auction, completed the demographic survey, and completed a follow-up call ($N = 87$)

Variable	Mean	Standard deviation
Occasional or daily e-cigarette user at follow up	45%	--
Previous serious attempt to quit cigarettes	72%	--
Advised to quit by healthcare professional	71%	--
Never smoke at home	36%	--
Ever used an e-cigarette	57%	--
Age	42	14
Female	53%	--
Nonwhite	44%	--
Some college	46%	--
Believe cigarettes more addictive than e-cigarettes	55%	--
Believe e-cigarettes less likely to cause cancer	38%	--
Rather quit smoking than use e-cigarettes	30%	--
Years smoking	22	13
Viewed video advertisement	29%	--
Viewed print advertisement	25%	--
Viewed both advertisements	31%	--
Bid for single-use e-cigarette	6.79	9.72

Notes: 432 current smokers took part in the auction. 336 completed at least one follow-up call, 94 of whom won one of the e-cigarettes during the auction experiment. Of these 94 auction winners, 87 answered all relevant demographic questions. Smokers were asked about e-cigarette use during a follow-up call. They were classified as an e-cigarette user if they indicated occasional or daily e-cigarette use during at least one of these calls. All other results come from a survey conducted during the auction experiment.

Table 2.

Random-effects probit average marginal effects estimating the probability of occasional or daily e-cigarette use at a follow-up call ($N = 87$)

Variable	dY/dX	Standard error
Previous serious quit attempt	0.19**	0.10
Advised to quit by healthcare professional	0.19***	0.07
Never smoke at home	0.06	0.07
Ever used an e-cigarette	0.13**	0.06
Age	0.00	0.00
Female	−0.15**	0.07
Nonwhite	−0.25***	0.068
College degree	−0.09	0.06
Believe cigarettes more addictive than e-cigarettes	0.03	0.069
Believe e-cigarettes less likely to cause cancer	−0.05	0.079
Rather quit smoking than use e-cigarettes	−0.15**	0.08
Years smoking	−0.00	0.00
Viewed video advertisement	0.15	0.11
Viewed print advertisement	−0.15	0.11
Viewed both advertisements	−0.02	0.11
Bid for single-use e-cigarette	−0.00	0.01
Six-week follow up	−0.04	0.06
Six-month follow up	−0.13**	0.06

** Significant at 0.05 level.

*** Significant at 0.01 level.