NBER WORKING PAPER SERIES

E-CIGARETTES AND ADULT SMOKING

Henry Saffer
Daniel Dench
Dhaval Dave
Michael Grossman

Working Paper 24212
http://www.nber.org/papers/w24212

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2018, Revised April 2018

This project was funded by grant number R01-DA039968 entitled "The Economics of Electronic Nicotine Delivery Systems: Advertising and Outcomes", from the National Institute of Health to the National Bureau of Economic Research, Inc. Thanks go to Donald Kenkel for comments on an earlier draft. This paper employs data from the A.C. Nielsen Company and was purchased from the Kilts Center of the University of the Chicago Booth School of Business. Results are calculated (or derived) based on data from The Nielsen Company (US), LLC and marketing databases provided by the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. Information about the data and access are available at http://research.chicagobooth.edu/nielsen/.

We are grateful to the A.C. Nielsen Company and the Kilts Center for providing the data and for instructions in its use. The conclusions drawn from the Nielsen data are those of the researchers and do not reflect the views of Nielsen. Nielsen is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein. All Rights Reserved. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

NBER working papers are circulated for discussion and comment purposes. They have not been peer-reviewed or been subject to the review by the NBER Board of Directors that accompanies official NBER publications.

E-cigarettes and Adult Smoking
Henry Saffer, Daniel Dench, Dhaval Dave, and Michael Grossman
NBER Working Paper No. 24212
January 2018, Revised April 2018
JEL No. I18

ABSTRACT

Over the past few years, adult use of e-cigs has been increasing while adult smoking has been declining. Although there is a negative time correlation, it is important to determine if there is a causal effect of e-cig use on smoking. This is important because of the known health hazards associated with smoking. A key concern with most prior studies of e-cigs and smoking is that causality between e-cig use and cigarette use is ignored. One contribution of this paper is to estimate structural and reduced form equations that replace e-cig use with e-cig price in order to avoid this endogeneity problem. The data employed to estimate the empirical models come from the Tobacco Use Supplements (TUS). These data are from the combined July 2014, January 2015 and May 2015 waves of the TUS. The results show that e-cig use increases the probability of a quit attempt, the probability of a quit failure, the number of quit failures and the probability of a quit success. It is also estimated that a 10% federal excise tax on e-cigs would reduce the number of quitters in the US by more than 250,000 per year.

Henry Saffer
NBER
5 Hanover Square, 16th Floor
Suite 1602
New York, NY 10004-2630
and NBER
hsaffer@gc.cuny.edu

Daniel Dench
The Graduate Center, CUNY
365 Fifth Avenue
New York, NY 10016
ddench@gradcenter.cuny.edu

Dhaval Dave
Bentley University
Department of Economics
175 Forest Street, AAC 195
Waltham, MA 02452-4705
and IZA
and also NBER
ddave@bentley.edu

Michael Grossman
National Bureau of Economic Research
5 Hanover Square, 16th Floor, Suite 1602
New York, NY 10004-2630
and and City University of New York
Graduate Center
and IZA
and also NBER
mgrossman@gc.cuny.edu

1. Introduction

There are a number of devices on the market today that deliver a dose of nicotine in vapor form to the user. These devices will be referred to as e-cigarettes (e-cigs) where the 'e' stands for electronic.[1] The first e-cigs were disposable and designed to resemble cigarettes. Today, refillable devices, which do not closely resemble cigarettes, are more common. A popular current device with the brand name Juul most closely resembles a flash drive. In all e-cigs a liquid containing propylene glycol and usually containing nicotine and sometimes containing added flavorings is vaporized by a battery powered heating element. There is no research on long-term health issues related to e-cig use, however, e-cigs are currently believed to be less dangerous than cigarettes because the vapor does not contain the toxins found in the smoke of a conventional cigarette (Goniewicz; et al. 2013; Czogala et al. 2014). The US National Institute on Drug Abuse states that because e-cigs deliver nicotine without burning tobacco, they appear to be a safer, less toxic alternative to conventional cigarettes.[2] The UK Public Health Department has taken a more definitive view and stated that e-cigs are significantly less harmful to health than tobacco.

Adult use of e-cigs has increased from 0.3% in 2010 to 3.2% in 2016 while adult smoking declined from 20.9% in 2005 to 15.1% in 2015. These time series cannot be interpreted as evidence that the use of e-cigs has causal effects on smoking. However, the effect of e-cig use on smoking is an important public health question because smoking is known to be hazardous. Although the public health impact of e-cigs depends on their effect on smoking, seven states have already passed legislation that requires a tax on e-cigarettes, which will deter the use of e-cigs.[3]

[1] In the literature, these devices are also referred to as electronic nicotine delivery systems.
[2] http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm173401.htm
https://www.drugabuse.gov/publications/drugfacts/electronic-cigarettes-e-cigs
[3] https://taxfoundation.org/vapor-taxes-2017/ As of January 2017, the seven states are California, Kansas, Louisiana, Minnesota, North Carolina, Pennsylvania, and West Virginia. Also, the District of Columbia, Puerto Rico and the U.S. Virgin Islands have a tax.

2. Prior Studies

One group of prior studies finds that e-cigs are associated with reduced smoking. Zhu et al. (2017) finds that those who report use of e-cigs had a higher smoking cessation rate than those who report no use of e-cigs. They relied on data from the Tobacco Use Supplements. Brown et al. (2014) assessed the effectiveness of e-cigs when used to aid smoking cessation in comparison with nicotine replacement therapy (NRT) and with unaided quitting. They rely on a cross-sectional survey of the English population that includes 5863 adults who had smoked within the previous 12 months and made at least one quit attempt during that period with either e-cigs, NRT or no aid. They found that e-cig users were more likely to report abstinence than either those who used NRT or no aid. That is, e-cig users were more likely to have quit smoking than either the users of NRT or those using no aid. Zhuang et al. (2016) argue that a common pattern is dual cigarette and e-cig use and that this dual use might delay the cessation of cigarette smoking. They rely on a nationally representative sample of 2028 US smokers from 2012 and 2014. Long-term e-cig use was defined as using e-cigs at baseline and follow-up. Use of e-cigs only at baseline or at follow-up was defined as short-term use. Non-users are defined as those that did not use e-cigs at either survey. Quit attempt rates and cessation rates were compared across the three groups. At the follow-up, long-term e-cig users had a higher quit attempt rate and a higher cessation rate than either short-term users or non-users. Among those making a quit attempt, use of e-cigs as a cessation aid surpassed that of FDA-approved pharmacotherapy. They conclude that short-term e-cig use was associated with a lower rate of smoking cessation but that long-term use of e-cigs was associated with a higher rate of smoking cessation.

Another group of studies finds that e-cigs are not associated with reduced smoking. Grana, Benowitz, and Glantz (2014) have argued that although e-cig use may reduce smoking it also may inhibit complete smoking cessation. Kalkhoran and Glantz (2016) provide a review of papers that attempt to assess the relationship between e-cig use and smoking cessation by

adult smokers. The question they are interested in is whether cigarette smokers who report e-cig use have a higher or lower probability of quitting smoking. They found 38 studies including two randomized controlled trials. These studies include Brown et al. (2014) referenced above. The two randomized controlled trials showed that e-cigs increased the probability of quitting. However, these studies relied on relatively small samples. Kalkhoran and Glantz (2016) conclude that these studies as a group predict that the probability of a successful quit is 28% lower for those who used e-cigs compared with those who did not use e-cigs. That is, e-cig use is associated with significantly less quitting among smokers.

3. Approach

A key concern with most prior studies of e-cigs and smoking is that endogeneity between e-cig use and cigarette use is ignored. There could be causality in both directions or use of both products could be driven by the same underlying unobserved factor. An example of an underlying unobserved factor is a desire to quit smoking, which is related to the demand for health. A greater unobserved desire to quit for health reasons could increase e-cigarette use and increase quits with no causal effect of e-cigs on quitting. Alternatively, an unobserved demand for nicotine might result in both greater e-cig use and a reduced probability of quitting smoking. This is seen in the case of smokers who use e-cigs in places where smoking is not allowed, which reduces the necessity to quit. Either dual causality or underlying unobserved factors will bias the estimation results. One contribution of this paper is to estimate structural and reduced form equations in order to avoid this endogeneity problem. The most relevant outcome is successful quitting but the effect of e-cigs on attempts to quit can provide more insight into the process. Because attempts can result in either failure or success, we also estimate the effect of e-cigs on failures to quit.[4]

[4] E-cigs could also affect the probability of starting to smoke although this is mainly limited to adolescents. This project focuses on adults so the question of initiation is not relevant.

The empirical model consists of the following three equations. The first is a standard demand equation for e-cigs:

(1) ECIG = E (e-cig prices, cigarette prices, demographics, fixed effects),

The second equation is a quit function, which has also been used in prior studies.

(2) Quit = Q (ECIG, cigarette prices, demographics, fixed effect).

Because the estimated effect of e-cigs in this quit function is likely to be biased due to endogeneity between e-cigs and cigarettes, equation (3), which is a reduced form of equations (1) and (2), is defined with the e-cig variable replaced by determinants of e-cig demand.

(3) Quit = Q (e-cig prices, cigarette prices, demographics, fixed effect).

The estimation of equation (3) eliminates the endogeneity between quitting and e-cig use in equation (2). Equation (3) is estimated for all attempts, failed quit attempts, the number of failed quit attempts and successful quit attempts.

One concern with this approach is whether the empirical version of equation (1) can be interpreted as a demand for e-cigs. E-cig prices are a function of supply and demand. We expect that in a supply and demand model, if demand was held constant, shifts in supply would reveal an inverse relationship between price and use. In the empirical models, we use a set of demographic variables, the price of cigarettes and state and time fixed effects to control demand. Cigarette prices are included in the e-cig demand function as the price of a potentially related good. The regressions of equation (1) test the relationship between e-cig price and use and a negative effect of e-cig prices on e-cig use is expected.

4. The Data

The data employed to estimate the empirical models come from the 2014-2015 Tobacco Use Supplements (TUS), which are sponsored by the National Cancer Institute and are based on a subsample of the Census Bureau's Current Population Survey (CPS). The TUS provide an extensive set of variables regarding tobacco products for adults ages 18 and over. The TUS

began asking questions about e-cig use in 2014 continuing in 2015. The data employed in this study rely on the combined July 2014, January 2015 and May 2015 waves of the TUS. These waves of the CPS includes about 450,000 individuals who are eligible for the TUS but only about 230,000 choose to participate in the TUS. The TUS then limits the survey to those who respond that they smoked at least 100 cigarettes during their lifetime. This reduced the sample to about 91,000. The TUS has additional screens on who is asked questions about smoking and e-cig use.[5] All of the quit related variables are defined for individuals who reported that they smoked last year. The public use version of the TUS identifies counties with a population of over 100,000. There are 368 identified counties included in the TUS and these counties represent about 40% of the US population. For simplicity, we will refer to the counties with over 100,000 individuals as urban and the other counties as rural.

The dependent variables include dichotomous measures of e-cig use, quit attempts, failed quits and successful quits. A variable measuring the number of failed quits is included in addition to the dichotomous failed quit variable. This variable includes the value zero for those who had no quit attempts. Successful attempts are defined as attempts that result in cessation for 90 days or more.

Both continuous and dichotomous independent variables were also defined. The continuous variables measure age, family income (divided by 1,000), number of children and years of education. The dichotomous variables measure Married, Male, Black, and Hispanic status. The dichotomous variables are equal to one if the individual is in the category defined by the variable name.

Measures of cigarette prices and e-cig prices were extracted from the Nielsen Retail Scanner data set. The Nielsen data are derived from supermarkets, drugstores convenience

[5] For example, the TUS only asks individuals who said they ever used e-cigs if they now use e-cigs with individuals who never used e-cigs given a missing value. For the e-cig use variable everyone who was not asked the question because they had responded earlier that they never used e-cigs and who reported that they smoked last year were recoded from missing to 0.

stores, liquor stores and mass merchandisers. One concern with the price data is that vape shops are not included. However, it is probable that vape shop prices are highly correlated with prices in other nearby stores. Another concern is the percent of e-cigs bought by adults on the internet. According to the 2014-2015 Population Assessment of Tobacco and Health Survey only 9.5% of adults buy their e-cigs online. Thus, retail store prices are probably a good approximation of actual prices paid by adults. E-cigs come in disposable and reusable forms. Disposable e-cigs provide fixed amount of nicotine and then must be disposed of. Reusable e-cigs involve buying a starter kit and then buying replacements. The first e-cigs were disposable but the reusable form is more common today. The Nielsen Retail Scanner data are limited to 65 large metro areas. Because a number of identified counties had no price data, or very few reporting stores, average state level prices were used. These state level prices were averaged at the state and wave level. Thus, the state prices are the average price in the state's urban counties only. The regressions are therefore limited to individuals who are identified in the TUS as living in large counties. So the price variable is a state level variable but reflects only prices in urban counties, the regressions are limited to individuals in the TUS who live in urban counties.

Table 1 presents weighted means and standard errors for the primary variables used in the analysis for those who used e-cigs and those who did not use e-cigs. The purpose of this table is to examine the descriptive data on differences between e-cig users and non-users in quit attempts, failures, number of failures, successes and demographics. The data in Table 1 are very similar to the data presented by Zhu et al. (2017) who also used the TUS. Data are presented first for those who report using e-cigs and second for those who report not using e-cigs. The variables quit attempts, failures, number of failures and successes are each defined as the percent of the full sample, which is everyone who reported smoking last year and lived in an urban county. For example, for all individuals who reported smoking last year and who lived in urban counties, about 46% of e-cig users attempted to quit while about 29% of non-e-cig

Table 1

Weighted Means or Percentages for E-cig Users and Non-E-cig Users 2014-2015 TUS Urban County Data for those Reporting Smoking Last Year

	Using E-cigs		Not Using E-cigs	
	Mean/%	SD	Mean/%	SD
Attempt to Quit	0.4563	0.4983	0.2886	0.4531
Failed to Quit	0.3589	0.4799	0.2185	0.4133
Number of Quit Failures in past 12 months [1]	0.9680	1.4563	0.5266	1.1392
Successful Quit for 90 days or more	0.0974	0.2966	0.0700	0.2552
Age	42.8100	15.0986	45.8598	15.1789
Family Income [2]	56.4372	42.3046	51.7442	39.5633
Employed	0.6308	0.4828	0.5980	0.4903
Male	0.5248	0.4996	0.5566	0.4968
Education	13.2877	1.9286	12.8705	2.3876
Married	0.4050	0.4911	0.3920	0.4882
Child	0.4831	0.8911	0.4596	0.9020
Black	0.0743	0.2624	0.1431	0.3502
Hispanic	0.0945	0.2927	0.1445	0.3516
N	1,322		10,662	

[1] Includes zero quit failures. [2] Scaled by 1,000. SD is the standard deviation

users attempted to quit. About 36% of the e-cig using sample reported failing and about 10% reported succeeding. The corresponding values for non-e-cig users are 22% and 7%. Table 1 also shows that adult e-cig users are somewhat older, more likely to be married and less likely to have minority status than adult non-e-cig users. Table 1 also shows that successful quits as a percentage of attempts for e-cig users is somewhat smaller than for non-e-cig users. The values are 21% for e-cig users and 24% for non-e-cig users. The reason that a greater

percentage of e-cig users are successful quitters is that there are more attempts by e-cig users than non-e-cig users.

An important statistical question, which is unclear from the descriptive data, is whether e-cig users differ in their interest in quitting from non-e-cig users. That is, uncontrolled individual heterogeneity between the groups may influence the data on attempts, failures and successes reported in table 1. Two sources of heterogeneity described above are the demand for health and the demand for nicotine. There are four questions in the TUS that provide some insight on this issue. These questions are asked only of e-cig users about why they use e-cigs. The questions are: 1) because they are allowed at times when, or in places where, smoking cigarettes isn't allowed, 2) because they might be less harmful to me than cigarettes, 3) because they might be less harmful to people around me than cigarettes and 4) because they help people to quit smoking cigarettes. Response to the first question, which is about the demand for nicotine, was 57% positive. Responses to the next three questions, which are about the demand for health, were 75%, 79% and 78% positive, respectively. Non-e-cig users probably view e-cigs less favorably. Also, table 1 shows that education and income, which are positively correlated with the demand for health, are both higher for e-cig users than non-e-cig users. These data suggest that the use of e-cigs is not random but motivated by the demand for nicotine and the demand for health. The contribution of this paper is to avoid this endogeneity and test for causal effects of e-cigs on smoking as described in Section 3.

Table 2 presents weighted means and standard deviations for individuals who reported smoking last year for urban and for rural counties. The purpose of this table is to examine the means for these groups because in the empirical work to follow we estimate regressions only for individuals in urban counties. These data show that the two groups are not significantly different in e-cig use, quit attempts, failures and successes. However, the urban counties do differ

Table 2

Weighted Means or Percentages for Urban and Rural Counties
2014-2015 TUS Data for Those Who Reported Smoking Last Year

	Urban		Rural	
	Mean/%	SD	Mean/%	SD
Use E-cigs	0.1133	.3170	0.1140	0.3179
Attempt to Quit	0.3076	0.4615	0.3102	0.4626
Failed to Quit	0.2344	0.4237	0.2430	0.4289
Number of Quit Failures in past 12 months [1]	0.5766	1.1876	0.5951	1.1999
Successful Quit for 90 days or more	0.0731	0.2604	0.0672	0.2504
Age	45.5143	15.1999	45.0653	15.1805
Family Income [2]	52.2759	39.9092	45.7234	36.3970
Employed	0.6017	0.4896	0.5824	0.4932
Male	0.5530	0.4972	0.5334	0.4989
Education	12.9178	2.3438	12.6869	2.1576
Married	0.3935	0.4885	0.4202	0.4936
Child	0.4623	0.9008	0.5286	0.9791
Black	0.1353	0.3421	0.1141	0.3180
Hispanic	0.1388	0.3458	0.0695	0.2543
N	11,984		22,311	

[1] Includes zero quit failures. [2] Scaled by 1,000. SD is the standard deviation

somewhat by demographics. The demographics are controlled in all the regressions so it is reasonable to extrapolate the results from the regression of urban smokers to rural smokers.

Table 3 presents summary data for the price variables. The cigarette price is per cigarette. The standard deviations and the minimum and maximum data show that there is

Table 3

Summary Statistics for the Price Data

	Price Cigarette[1]	Price Starter Kit	Price of Replacement	Price of Disposable
Mean	0.2879	21.578	3.5413	7.8324
SD	0.06500	2.3383	0.3995	1.2070
Min	0.1212	13.4200	2.5793	5.9756
Max	0.4992	57.0500	9.2538	2.5007
R^2	0.9686	0.4530	0.8618	0.8949
Correlation Matrix				
Price Cigarette[1]	1			
Price Starter Kit	0.1451	1		
Price of Replacement	-0.0333	0.0974	1	
Price of Disposable	0.3400	0.0679	-0.5353	1

[1] Price per cigarette, which is equal to $5.76 per pack. 153 unique observations. R^2 is from OLS regressions of each price variable on all the state and wave fixed effects used in the regressions presented in tables 4-8. All the data are based on the merged TUS-Nielsen sample, which weights the data in proportion to the state's urban population.

variation across states and waves in these prices. Cigarette prices vary because of differences in state excise taxes, transportation costs and retailing costs. E-cigs are only taxed in a few locations and marketing is typically more at a local level than in the case of cigarettes. E-cig prices vary across states because of transportation costs, local retailer costs and local marketing costs. The R-square is from regressions of the price variable on all the fixed effects used in the regressions presented in tables 4-8. These values show that much of the variations in price are accounted for by the fixed effects particularly in the case of cigarettes. This correlation between price and fixed effects can affect the significance levels. The regressions in

tables 4-8 present alternative sets of prices, which provide some test for robustness with respect to choice of price variables. Dropping the fixed effects would create other concerns. The bottom of table 3 presents the correlations between the price variables. Some of these correlations are large and could also present problems with significance in the estimation models. These data problems are due in some measure to the relative newness of e-cigs which results in a fairly short time dimension in the data.

5. Results

Tables 4-8 present the regression results for e-cig demand and for the quit related variables. All of the regressions include state and wave fixed effects variables and standard errors clustered at state level. The tables include alternative combinations of cigarette prices, starter kit prices, replacement prices and disposable prices. Each table presents the same set of alternative price specifications. All of the regressions also use the same set of non-price independent variables and are either logits or ordered logits. All of the regressions are based on individuals who report that they smoked last year and live in urban counties. The reported values are coefficients not marginal effects. In addition to coefficients, marginal effects and elasticities are reported for all significant e-cig price variables.[6]

Table 4 presents logit results for e-cig use. In the four regressions presented in table 4 the replacement price is always negative but only significant in one regression. The replacement price in the other three regressions has relatively low p-values but they are greater than 0.10. The own price elasticity for e-cig participation based on the second specification and

[6] The dependent variables, with one exception are dichotomous. These variables can be interpreted as rates. The elasticity is the effect of a percentage increase in price on the percentage change in the rate. For example, if the elasticity were 1, a 10 percent increase in the price would resulted in a 10 percent decline in the rate and if the rate were .10 it would decline to .09.

Table 4

Coefficients from Logit Regressions of E-cig Demand
Smoked Last Year

	E-cig	E-cig	E-cig	E-cig
Age	-0.0144***	-0.0144***	-0.0144***	-0.0144***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Family Income	0.0013*	0.0013*	0.0013*	0.0013*
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Employed	-0.0828	-0.0817	-0.0828	-0.0826
	(0.0777)	(0.0775)	(0.0775)	(0.0777)
Male	-0.1310***	-0.1312***	-0.1305***	-0.1314***
	(0.0485)	(0.0484)	(0.0485)	(0.0483)
Education	0.0488***	0.0484***	0.0488***	0.0487***
	(0.0126)	(0.0126)	(0.0126)	(0.0126)
Married	0.0529	0.0522	0.0545	0.0525
	(0.0692)	(0.0691)	(0.0689)	(0.0691)
Child	-0.0603	-0.0599	-0.0609*	-0.0602
	(0.0369)	(0.0369)	(0.0369)	(0.0369)
Black	-0.6934***	-0.6940***	-0.6944***	-0.6929***
	(0.1232)	(0.1231)	(0.1230)	(0.1234)
Hispanic	-0.3631***	-0.3642***	-0.3620***	-0.3632***
	(0.0987)	(0.0987)	(0.0989)	(0.0987)
Price Cigarette	28.4066*	21.3701		25.7937*
	(15.2060)	(15.0726)		(14.8287)
Price Starter Kit	0.029		0.0249	0.0264
	(0.0180)		(0.0190)	(0.0188)
Price of Replacement	-0.3596	**-0.4289*** **-0.0415**[3] **-1.2755**[4]	-0.3412	-0.3767
	(0.2614)	**(0.2460)**	(0.2766)	(0.2498)
Price of Disposable		0.1932		0.1619
		(0.1717)		(0.1817)
Pseudo R-Square	0.0318	0.0317	0.0316	0.0318
N	11621	11621	11621	11621

*** p<0.01, ** p<0.05, * p<0.10. Wave and state fixed effects included in all regressions. Standard errors clustered at the state level. [3] marginal effect. [4] elasticity.

the replacement price is estimated at -1.28. This is relatively high compared to own price elasticity for cigarettes from past studies. The elastic demand suggests that good substitutes for e-cigs are available. The cigarette price coefficients are positive in the three regressions that

include this variable and significant in two of these regressions. The positive coefficient suggests substitution between e-cigs and cigarettes. Age, Male, Education and minority status are all negative and significant. We conclude it is likely that the empirical relationship between e-cig use and e-cig price is negative and that the relationship between cigarette prices and e-cig use is positive although greater significance levels would have increased our confidence in this result.

Table 5 presents logit estimates on the effect of e-cig prices on quit attempts. The price of replacements is negative and significant. That is, e-cig use is positively related to the probability of a quit attempt. Also, Income and Male are negatively related to quit attempts while Education, Child and Black are positively related to quit attempts. This is similar to the result for attempts that is shown in table 1 with descriptive data only. That is, e-cig users make more quit attempts.

Table 6 presents the logit results for probability of a quit failure and Table 7 presents the results for the number of quit failures. The regressions for the number of failed quit tries are order logit regressions because the dependent variable includes four ordered outcomes, including zero attempts.[7] In all eight regressions, the price of replacements is negative and is significant in six. There are specific estimates for the marginal effects and for the elasticities for each outcome of an ordered logit. The values reported are for the outcome 2-3 times. The results show that e-cig use is positively related to the probability of a quit failure and to the number of quit failures. As e-cig use goes up the probability of a failed quit goes up and the number of failed quits goes up because e-cig use increases the number of quit attempts. Most attempts result in failure but an increase in attempts increases the probability of an ultimate

[7] Estimation was by order logit rather than by a count procedure because the variable has an uneven metric (never, once, 2-3 times, 4 or more times).

success. Also, Income and Male are negative and significant while Black and Child are positive and significant.

Table 5
Logit Regressions of the Probability of an Attempt
Smoked Last Year

	Attempts	Attempts	Attempts	Attempts
Age	-0.0023	-0.0023	-0.0023	-0.0023
	(0.0016)	(0.0016)	(0.0016)	(0.0016)
Family Income	-0.0029***	-0.0029***	-0.0029***	-0.0029***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Employed	-0.0819	-0.0817	-0.082	-0.0818
	(0.0511)	(0.0513)	(0.0511)	(0.0512)
Male	-0.2508***	-0.2510***	-0.2508***	-0.2510***
	(0.0430)	(0.0428)	(0.0429)	(0.0429)
Education	0.0606***	0.0606***	0.0606***	0.0606***
	(0.0105)	(0.0105)	(0.0105)	(0.0105)
Married	-0.0391	-0.0395	-0.0391	-0.0394
	(0.0468)	(0.0468)	(0.0468)	(0.0468)
Child	0.0968***	0.0969***	0.0968***	0.0969***
	(0.0233)	(0.0233)	(0.0234)	(0.0233)
Black	0.1106**	0.1108**	0.1105**	0.1110**
	(0.0557)	(0.0565)	(0.0557)	(0.0561)
Hispanic	-0.0538	-0.0541	-0.0537	-0.0539
	(0.0902)	(0.0900)	(0.0902)	(0.0901)
Price Cigarette	1.7364	-1.1414		-0.5341
	(10.3640)	(11.9848)		(11.3081)
Price Starter Kit	0.0052		0.0049	0.0035
	(0.0220)		(0.0221)	(0.0218)
Price of Replacement	**-0.3873*** **-0.0814**[3] **-0.8913**[4]	**-0.4078*** **-0.0857**[3] **-0.9385**[4]	**-0.3853*** **-0.0809**[3] **-0.8866**[4]	**-0.4030*** **-0.0847**[3] **-0.9274**[4]
	(0.2303)	**(0.2414)**	**(0.2298)**	**(0.2286)**
Price of Disposable		0.1022		0.0983
		(0.1524)		(0.1476)
Pseudo R-Square	0.0167	0.0167	0.0167	0.0167
N	11730	11730	11730	11730

*** p<0.01, ** p<0.05, * p<0.10. Wave and state fixed effects variables included in all regressions. Standard errors clustered at the state level. [3] marginal effect. [4] elasticity.

Table 6
Coefficients from Logit Regressions of the Probability of a Quit Failure
Smoked Last Year

	Probability Quit Failures	Probability Quit Failures	Probability Quit Failures	Probability Quit Failures
Age	0.0003	0.0003	0.0003	0.0003
	(0.0016)	(0.0016)	(0.0016)	(0.0016)
Family Income	-0.0038***	-0.0038***	-0.0038***	-0.0038***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Employed	-0.0568	-0.0559	-0.0569	-0.0566
	(0.0456)	(0.0458)	(0.0456)	(0.0458)
Male	-0.2541***	-0.2540***	-0.2540***	-0.2543***
	(0.0494)	(0.0494)	(0.0493)	(0.0494)
Education	0.0185	0.0183	0.0185	0.0185
	(0.0117)	(0.0116)	(0.0117)	(0.0116)
Married	-0.0644	-0.0654	-0.0639	-0.0649
	(0.0544)	(0.0541)	(0.0545)	(0.0545)
Child	0.0611**	0.0614**	0.0608**	0.0613**
	(0.0246)	(0.0245)	(0.0246)	(0.0246)
Black	0.2434***	0.2422***	0.2431***	0.2440***
	(0.0914)	(0.0919)	(0.0915)	(0.0918)
Hispanic	-0.0201	-0.0212	-0.0199	-0.0202
	(0.1008)	(0.1004)	(0.1009)	(0.1007)
Price Cigarette	10.345	2.2453		6.9695
	(14.8121)	(15.6217)		(15.0938)
Price Starter Kit	0.03		0.0284	0.0275
	(0.0221)		(0.0224)	(0.0223)
Price of Replacement	**-0.3484*** **-.0618**[3] **-.8892**[4]	**-0.4052*** **-.0719**[3] **-1.0341**[4]	-0.3363	**-0.3715*** **-.0659**[3] **-.9480**[4]
	(0.1980)	**(0.2189)**	(0.2076)	**(0.1934)**
Price of Disposable		0.1788		0.1476
		(0.1414)		(0.1405)
Pseudo R-Square	0.0172	0.0172	0.0172	0.0173
N	11730	11730	11730	11730

***p<0.01, ** p<0.05, * p<0.10. Wave and state fixed effects variables included in all regressions. Standard errors clustered at the state level. [3] marginal effect. [4] elasticity.

Table 7
Coefficients from Ordered Logit Regressions of the Number of Quit Failures Smoked Last Year

	Number of Quit Failures	Number of Quit Failures	Number of Quit Failures	Number of Quit Failures
Age	0.0006	0.0006	0.0006	0.0006
	(0.0016)	(0.0016)	(0.0016)	(0.0016)
Family Income	-0.0037***	-0.0037***	-0.0037***	-0.0037***
	(0.0006)	(0.0007)	(0.0006)	(0.0007)
Employed	-0.0509	-0.0501	-0.0511	-0.0508
	(0.0459)	(0.0462)	(0.0459)	(0.0461)
Male	-0.2492***	-0.2494***	-0.2491***	-0.2494***
	(0.0498)	(0.0498)	(0.0497)	(0.0498)
Education	0.0199*	0.0196*	0.0198*	0.0198*
	(0.0111)	(0.0111)	(0.0111)	(0.0111)
Married	-0.0675	-0.0684	-0.0671	-0.068
	(0.0484)	(0.0481)	(0.0485)	(0.0485)
Child	0.0572**	0.0572**	0.0570**	0.0573**
	(0.0229)	(0.0228)	(0.0229)	(0.0229)
Black	0.2751***	0.2740***	0.2748***	0.2759***
	(0.0929)	(0.0937)	(0.0929)	(0.0934)
Hispanic	-0.0193	-0.02	-0.0191	-0.0194
	(0.1012)	(0.1010)	(0.1013)	(0.1011)
Price Cigarette	10.2824	1.6985		6.5177
	(14.0815)	(14.7797)		(14.2384)
Price Starter Kit	0.0305		0.0289	0.0276
	(0.0206)		(0.0210)	(0.0207)
Price of Replacement	**-0.3340*** **-.0238**[3] **-.8588**[4]	**-0.3943*** **-.02806**[3] **-1.0138**[4]	-0.322	**-0.3600*** **-.02561**[3] **-.92547**[4]
	(0.1904)	**(0.2105)**	(0.2026)	**(0.1844)**
Price Disposable		0.1931		0.1612
		(0.1463)		(0.1451)
Pseudo R-Square	0.0120	0.0120	0.0120	0.0121
N	11730	11730	11730	11730

*** p<0.01, ** p<0.05, * p<0.10. Wave and state fixed effects variables included in all regressions. Standard errors clustered at the state level. The dependent variable includes zero quit failures. [3] marginal effect for 2 to 3 tries. [4] elasticity effect for 2 to 3 tries.

Table 8 presents the results for quit successes. The price of replacements is negative but not significant while the price of starter kits is negative and significant. In the prior regression, the replacement price was generally significant while the starter kit price was not. Tests of joint significance show that these two variables are jointly significant at about 5% in the regressions where they both are included. The regressions show that greater e-cig use increases the probability of a successful quit. This is consistent with the descriptive data presented in table 2, which also show that e-cig use increases success. The elasticity for starter kits was estimated at -1.27 and the elasticity for replacements was estimated at about -1. Age, Black and Hispanic are negatively related to successes while Education is positively related to successes.

A relevant follow-up question is how an e-cig excise tax would affect the number of successful quits. As noted above seven states and the District of Columbia have taxes on e-cigs. Many other states have also considered a tax on e-cigs. The Food and Drug Administration has the authority to regulate e-cigs but this has not yet resulted in a federal excise taxes on e-cigs.[8] The effect of an e-cig excise tax can be estimated with the elasticities estimated in table 8. We assume a conservation value of -1.0 and assume a federal excise tax, increases retail prices by 10%. The elasticities imply that this tax would reduce the successful quit rate by about 10%. The successful quit rate for all smokers is about 7.3% and a 10% reduction would result in a successful quit rate of about 6.6%. About 36 million Americans smoke and, assuming that 7.3% successful quits each year, about 2.6 million American

[8] https://www.bna.com/extras-excise-states-b73014449960/

Table 8
Coefficients from Logit Regressions of the Probability of a Quit Success
Smoked Last Year

	Quit Successes	Quit Successes	Quit Successes	Quit Successes
Age	-0.0086***	-0.0086***	-0.0086***	-0.0086***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Family Income	0.0002	0.0002	0.0002	0.0002
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Employed	-0.0919	-0.0937	-0.092	-0.092
	(0.0856)	(0.0855)	(0.0856)	(0.0857)
Male	-0.1188	-0.1194	-0.1191	-0.1186
	(0.0795)	(0.0794)	(0.0795)	(0.0795)
Education	0.1460***	0.1468***	0.1460***	0.1460***
	(0.0187)	(0.0187)	(0.0187)	(0.0188)
Married	0.0548	0.0557	0.0532	0.0551
	(0.0695)	(0.0693)	(0.0695)	(0.0696)
Child	0.1309***	0.1307***	0.1318***	0.1309***
	(0.0365)	(0.0367)	(0.0365)	(0.0366)
Black	-0.3718**	-0.3667**	-0.3705**	-0.3724**
	(0.1541)	(0.1528)	(0.1545)	(0.1541)
Hispanic	-0.1396*	-0.1381*	-0.1399*	-0.1393*
	(0.0841)	(0.0839)	(0.0844)	(0.0842)
Price Cigarette	-24.9004	-11.0057		-23.0566
	(17.5523)	(19.0842)		(18.9008)
Price Starter Kit	**-0.0643** **-.0044**[3] **-1.3066**[4]		**-0.0599*** **-.0046**[3] **-1.2173**[4]	**-0.0628**** **-.00432**[3] **-1.2769**[4]
	(0.0323)		**(0.0322)**	**(0.0320)**
Price of Replacement	-0.3212 -.0218[3] -.9944[4]	-0.1742 -.01180[3] -.53909[4]	-0.3550 -.0240[3] -1.0990[4]	-0.3083 -.02088[3] -.95430[4]
	(0.3358)	(0.3428)	(0.3391)	(0.3371)
Price of Disposables		-0.1500		-0.0735
		(0.1978)		(0.1908)
Pseudo R-Square	0.0339	0.0332	0.0338	0.0339
N	11730	11730	11730	11730

*** p<0.01, ** p<0.05, * p<0.10. Wave and state fixed effects variables included in all regressions. Standard Errors clustered at the state level. [3] marginal effect. [4] elasticity.

smokers quit each year.[9] A 10% increase in the price of e-cigs would reduce the number of quitters by about 250,000 smokers.

C. Conclusions

The results suggest that there is a positive causal effect of e-cig use on attempts to quit smoking, on failures to quit smoking and on success in quitting smoking, although greater significance levels would have made a stronger case. The replacement price was generally the most important e-cig price. The successful quit rate, given an attempt, is actually slightly smaller for e-cig users than non-e-cig users. The increase in the probability of a successful quit is the result of more attempts by e-cig users than by non-e-cig users. According to Chaiton et al. (2016), it can take six or more failed attempts before a smoker has a success. Thus, for many smokers a successful quit may only come after a number of failed attempts. The increased probability of an attempt and the increased number of failed attempts during the past year suggest that e-cig use helps to create this sequential process that leads to cessation. Overall, the results present a reasonable case for e-cigs as a useful aid to adults who are trying to quit smoking.

[9] These losses are somewhat offset by the addition of about 800,000 new smokers each year. These new smokers are young people some of whom may have begun smoking because of e-cig use as an adolescent.

References

Brown, Jamie, Emma Beard, Daniel Kotz, Susan Michie, and Robert West. 2014. "Real-world effectiveness of e-cigarettes when used to aid smoking cessation: a cross-sectional population study." *Addiction* 109(9): 1531-1540.

Chaiton, Michael, Lori Diemert, Joanna E. Cohen, Susan J. Bondy, Peter Selby, Anne Philipneri, and Robert Schwartz. 2016. "Estimating the number of quit attempts it takes to quit smoking successfully in a longitudinal cohort of smokers." *BMJ open* 6(6): e011045.

Czogala, Jan, Maciej L. Goniewicz, Bartlomiej Fidelus, Wioleta Zielinska-Danch, Mark J. Travers, and Andrzej Sobczak. 2014. “Secondhand Exposure to Vapors from Electronic Cigarettes.” *Nicotine & Tobacco Research* 16(6): 655-662.

Goniewicz, M.L., J. Knysak, M. Gawron, L. Kosmider, A. Sobczak, J. Kurek, A. Prokopowicz, M. Jablonska-Czapla, C. Rosik-Dulewska, C. Havel, P. Jacob, 3rd, and N. Benowitz. 2013. “Levels of Selected Carcinogens and Toxicants in Vapour from Electronic Cigarettes.” *Tobacco Control* 23(2): 133-9.

Grana, Rachel, Neal Benowitz, and Stanton A. Glantz. 2014. "E-cigarettes." *Circulation* 129(19): 1972-1986.

Kalkhoran, Sara, and Stanton A. Glantz. 2016. "E-cigs and smoking cessation in real-world and clinical settings: a systematic review and meta-analysis." *The Lancet Respiratory Medicine* 4(2): 116-128.

Zhu, Shu-Hong, Yue-Lin Zhuang, Shiushing Wong, Sharon E. Cummins, and Gary J. Tedeschi. 2017. "E-cigarette use and associated changes in population smoking cessation: evidence from US current population surveys." *BMJ* 358: j3262.

Zhuang, Yue-Lin, Sharon E. Cummins, Jessica Y. Sun, and Shu-Hong Zhu. 2016. "Long-term e-cigarette use and smoking cessation: a longitudinal study with US population." *Tobacco Control* 25(Suppl 1): i90-i95.