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Electronic Cigarette Risk Beliefs and Usage After the Vaping Illness Outbreak

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Electronic cigarette risk beliefs and usage after the vaping illness outbreak

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Abstract
New national survey evidence on electronic cigarette (e-cigarette) risk beliefs indicates that people substantially overestimate the health risks posed by e-cigarettes, both in absolute terms and relative to conventional cigarette risk beliefs. Perceptions of the lung cancer risks and total mortality risks of conventional cigarettes function as prior risk beliefs for e-cigarettes. People believe e-cigarettes are at least 60% as risky as conventional cigarettes. Whether respondents have seen reports of vaping-related illnesses has no significant effect on risk beliefs, but there has been a modest increase in the percentage who believe that e-cigarettes are riskier than cigarettes. Accurate e-cigarette beliefs would significantly increase whether people try, currently use, or exclusively use e-cigarettes. Whereas price and taste are the principal drivers of brand choice for conventional cigarettes, use of e-cigarettes is more closely linked to smoking cessation and concern with environmental tobacco smoke.

Keywords Electronic cigarettes · E-cigarettes · Vaping · Cigarettes · Smoking · Lung cancer · Mortality · Bayesian

JEL Classifications D80 · I12 · I18 · K32

1 Introduction

Perceived risks of electronic cigarettes (e-cigarettes), which are also called vaping devices, play a pivotal role with respect to potential market failure. Whether people have accurate assessments of the risks of e-cigarettes affects whether they are incurring risks or foregoing risks that they do not understand. If people underestimate the risks of

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vaping, the prevalence of e-cigarette usage will exceed the economically efficient amount. Overestimation of the risks creates errors in the opposite direction. Efficient choices between conventional cigarettes and vaping products depend on accurate perceptions of the comparative risks of conventional cigarettes and e-cigarettes. Much of the impetus for smoking e-cigarettes is to seek a safer alternative to conventional cigarettes. These comparative decisions could be flawed because of shortcomings in risk beliefs for e-cigarettes or failures to adequately perceive the relative risks of e-cigarettes compared to conventional cigarettes. The new survey results reported in this article document each of these potential market failures, as people greatly overestimate the risks posed by e-cigarettes and underestimate the risk reductions that can be achieved by vaping instead of smoking conventional cigarettes.

E-cigarettes are much safer than conventional cigarettes, but they are not entirely risk-free. Public health officials in the United States continue to warn people about the potential risks associated with e-cigarettes. These warnings escalated in 2019 after an outbreak in the United States of vaping-related illnesses and deaths. Even before this vaping illness crisis, risk beliefs regarding e-cigarettes were substantial. The survey results reported in Viscusi (2016) using survey data from 2014 found that the public had risk beliefs regarding e-cigarettes that far exceeded scientists' estimates of the risk levels. The late 2019 survey results reported in this article pertain to a more recent period during which e-cigarette usage has increased. Experience with the product provides consumers with additional information about e-cigarettes regarding short-term health impacts as well as physical effects that might signal potential risks, such as hoarseness in one's throat. In 2019 a new dimension to the risks emerged after a wave of acute vaping-related illnesses led to hospitalizations and some deaths. By considering the 2014 and 2019 survey data for comparable risk belief questions, this article examines risk beliefs before and after the vaping illness outbreak.

Section 2 provides a brief summary of the risk levels associated with e-cigarettes. Compared to conventional cigarettes, the risks posed by vaping are quite low based on all available evidence. Nevertheless, the wave of illnesses and deaths due to vaping that emerged in 2019 serves as a cautionary event. Section 3 reviews the sample characteristics of the 2019 survey that serves as the basis for the empirical analysis.

Two key health-related attributes of e-cigarettes are their potential health risks and their nicotine levels. Section 4 focuses on different measures of risk beliefs, including assessments of the lung cancer and mortality risks of e-cigarettes and the relative risk ratings of e-cigarettes compared to conventional cigarettes. The conceptualization of how people form risk beliefs and choose between smoking and vaping products is based on a Bayesian model. People who consider vaping can utilize a variety of sources of information to construct their risk beliefs, including knowledge of the functioning of vaping devices, statements by public health officials, risk levels for possibly related products such as conventional cigarettes, direct experience with the product, and information about health outcomes associated with vaping. The focus of Section 5 is on nicotine levels and related concerns such as the perceived difficulty of quitting e-cigarettes. Whereas health risks are an undesirable product attribute, consumers of e-cigarettes are likely to view the presence of nicotine in e-cigarettes positively, particularly for those using e-cigarettes as an alternative to conventional cigarettes.

The exploration of why people smoke e-cigarettes in Section 6 examines the extent to which the risk and nicotine properties of e-cigarettes influence consumer decisions to use

e-cigarettes. Concern with risk levels is a much more influential driver of e-cigarette decisions than any perceived differences between conventional cigarettes and e-cigarettes in nicotine levels, which are not influential in affecting whether a person smokes e-cigarettes. Vaping rates would increase if people had a better understanding of the risk-related properties of e-cigarettes. Accurate risk beliefs would increase whether people try e-cigarettes, currently use e-cigarettes, or exclusively use e-cigarettes based on all three risk measures—the relative risk beliefs, the lung cancer risk beliefs for cigarettes and e-cigarettes, and the mortality risk beliefs for cigarettes and e-cigarettes. Unlike conventional cigarettes, for which price and taste attributes play a dominant role in driving cigarette brand choice, consumers report that a variety of concerns involving risks to themselves and risks to others are the principal determinants of their decision to use e-cigarettes. Section 7 concludes that proper understanding of the risks and function of e-cigarettes requires that this product not be equated with conventional cigarettes that burn tobacco.

2 The risks of e-cigarettes

The risks of conventional cigarettes are among the most well documented hazards for any consumer product and have been the focus of scientific studies for over half a century. The mass production of cigarettes dates back to the late nineteenth century, resulting in a tremendous wealth of information about the relation between product use, illnesses, and mortality. These data provide the potential for epidemiological studies in which the health of smokers can be tracked over time and compared to that of reference groups of nonsmokers who otherwise would have experienced a similar health trajectory. Because many of the health consequences of cigarettes, such as cancer, involve a latency period that may extend for decades, having a long time period of data facilitates the estimation of the risks associated with cigarettes.

In contrast, e-cigarettes have been available for less than 20 years, and their use in the U.S. market extends to just over a decade. E-cigarettes are battery-powered devices that vaporize a liquid that generally includes nicotine. The time period for which data are available to assess the health risks of e-cigarettes is necessarily more limited than that for conventional cigarettes. However, assessment of the risks of e-cigarettes is not entirely speculative. For brands that are marketed nationally or can be obtained for testing, it is feasible to analyze the chemical composition and associated risks of vapors from e-cigarettes and to compare these risk exposures to tobacco smoke. It is also possible to monitor short-term health impacts for e-cigarette products.

The absence of the same level of information about e-cigarette risks and, in particular, the absence of epidemiological data, has led to proposals that e-cigarettes be banned until comparable evidence is available. This approach may involve a wait of several decades before e-cigarettes are cleared for purchase. Such purportedly protective proposals reflect an irrational response to risk ambiguity. They embody an extreme degree of ambiguity aversion, which is generally viewed as a behavioral anomaly inconsistent with rational choice (Ellsberg 1961; Viscusi 1998). Consider a person deciding whether to smoke a conventional cigarette that burns tobacco or to vape an e-cigarette, for which no tobacco is burned to create the vapor. The risks associated with cigarettes are substantial and precisely estimated based on decades of scientific studies. Even though the risks associated with e-cigarettes are less precisely understood, based

on the information available one would expect consumers to assign a lower probability of adverse health outcomes to e-cigarettes than to conventional cigarettes. The main caveat is that in thinking about the risks of any product it is important to take into account the possibility that there may be potential states of the world that are not currently known. For example, there was no general anticipation of the possibility of the vaping-related illnesses that occurred in 2019. Taking such possibilities into account is not a concern specifically related to risk ambiguity of a particular risk but rather the importance of thinking broadly about potential outcomes and spreading the tails of the subjective probability distribution sufficiently.

To simplify the discussion, suppose that the consumer is making a single-period decision so that multi-period complications such as learning by experience and evolving scientific studies over time do not enter. Suppose too that other than potential differences in risk, smoking a tobacco cigarette and vaping e-cigarettes are equally attractive from the standpoint of taste, price, and other considerations. If the assessed probability of adverse health effects is lower for e-cigarettes, but this probability is less precisely estimated than for conventional cigarettes, it is nevertheless always optimal for the consumer to choose the vaping product. The desirability of e-cigarettes becomes even greater in multi-period contexts. As demonstrated in Viscusi and DeAngelis (2018), people usually fail to take advantage of the superiority of the ambiguous choice in multi-period contexts involving lotteries between life and death. The more uncertain risks offer a greater chance for long-term survival in these situations. Policymakers likewise should not fall prey to ambiguity aversion by insisting that we await the development of long-run studies for e-cigarettes comparable to those that we have for conventional cigarettes. That approach would effectively ban e-cigarettes, lead more people to continue to smoke conventional cigarettes, have substantial adverse health effects, and reduce the development of epidemiological data based on impacts from e-cigarette use.

The aversion to e-cigarettes on the part of much of the U.S. public health community also may be the result of an additional irrational response on other dimensions as well. People tend to overreact to risks that are novel, and they also overestimate low probability risks (Kahneman and Tversky 1979; Fischhoff et al. 1981; Viscusi 1998). The risks posed by e-cigarettes or any new product are novel risks that people formerly would have set equal to zero. Becoming aware of these novel risks that are no longer viewed as zero probabilities may produce an alarmist response. The dangers of risk overestimation are particularly great if people base their assessment of the risks from e-cigarettes on the risks of conventional cigarettes despite the fundamental differences in the functioning of the products. Whether people overestimate or underestimate risks also depends in part on the magnitude of the risk. There is a greater tendency to overestimate small probabilities than large probabilities, so the comparatively low e-cigarette risks may tend to be prone to overestimation.

The available scientific evidence does not indicate that e-cigarettes are risk-free, but the evidence is consistent with a much lower risk level for e-cigarettes than for conventional cigarettes. Public Health England (2015, 2018) reviewed numerous meta-analyses and dozens of e-cigarette studies before concluding that e-cigarettes are about 95% safer than conventional cigarettes. Public Health England has publicized this conclusion and has urged people to vape e-cigarettes rather than smoke conventional cigarettes. The National Academies of Sciences, Engineering, and Medicine (2018) report is more cautious in its assessment, noting that it did not know what the

long-run effects of e-cigarettes would be. U.S. government agencies continue to oppose all forms of smoking behaviors, making few if any distinctions for e-cigarettes. The Food and Drug Administration extended the definition of tobacco products to include electronic delivery systems such as e-cigarettes (21 CFR Parts 1100, 1140, and 1143), and on Dec. 20, 2019 the federal minimum purchase age for sale of tobacco products, including e-cigarettes, increased from 18 to 21.

The systematic review of the scientific literature by Farsalinos and Polosa (2014) concluded that the risks of conventional cigarettes dwarf the risks from e-cigarettes. Analysis of the nitrosamines associated with these products indicates that conventional cigarettes have nitrosamine levels 971 to 1806 times as great as for e-cigarettes. Stephens (2018) found that the cancer potency of e-cigarettes was less than 1% of that of conventional cigarettes. The summary review of e-cigarettes by Public Health England (2018) led to the following synthesis: "It concluded that the cancer potencies of e-cigarettes were largely under 0.5% of the risks of smoking." Similarly, the presence of toxic chemicals such as heavy metals in e-cigarettes is also quite different, with conventional cigarettes receiving a score of 100–134 for their toxic emissions, as compared to a score of 0 for e-cigarettes (Farsalinos and Polosa 2014). There have also been toxicological studies of the effects on human embryonic stem cells, for which conventional cigarettes have very potent levels of toxicity, while e-cigarettes have only very marginal risks. Effects of e-cigarettes and conventional cigarettes on blood pressure are also different, with e-cigarettes leading to lower elevations of systolic and diastolic blood pressure than conventional cigarettes.

Given the relative risk levels of cigarettes and e-cigarettes, switching to e-cigarettes by smokers would provide an unambiguous public health gain. Even if the presence of e-cigarettes leads people who would otherwise not be smokers to begin vaping, any reduction in smoking prevalence rates because some people have stopped smoking would likely offset the risks from nonsmokers taking up vaping. At a more fundamental level, the policy objective should not be to minimize adverse health impacts and to require that all products be risk-free. Rather, the task is to promote efficient levels of risk taking in all dimensions of choice.

Smoking also may generate external harms to others through environmental tobacco smoke for conventional cigarettes and from the vapors emitted by e-cigarettes. Farsalinos and Polosa (2014) and McAuley et al. (2012) concluded that the evidence regarding secondhand smoke from e-cigarettes indicated that the risks were lower than those posed by conventional cigarettes for two reasons. Unlike cigarettes that emit smoke even when puffs are not being taken, e-cigarettes only emit vapors when the person activates the device and takes a puff. In addition, e-cigarette vapors are less toxic than tobacco smoke, so that they pose lower degrees of risk. Similarly, but more cautiously, the National Academies of Sciences, Engineering, and Medicine (2018) report concluded: "There is moderate evidence that secondhand exposure to nicotine and particulates is lower from e-cigarettes compared with combustible tobacco cigarettes."

Another dimension of interest is whether e-cigarettes are addictive. Nicotine levels are of independent concern in that they relate to the difficulty of quitting smoking or vaping. Nicotine is not a risk factor similar to that of toxic chemicals. For example, the International Agency for Research on Cancer does not list nicotine as a carcinogen. Unlike tobacco smoke generally, nicotine does not increase the risk of cardiovascular

disease, obstructive lung disease, or other adverse health impacts. However, nicotine may affect brain development for adolescents, providing the impetus for age-related restrictions on use of e-cigarettes (U.S. Department of Health and Human Services 2014). E-cigarettes also may adversely affect maternal and infant health.

It also may not be feasible for consumers to accurately monitor the nicotine level of e-cigarettes. While average nicotine levels per vaping puff are lower than for conventional cigarettes, how a person smokes e-cigarettes can affect the amount of nicotine being delivered. Nicotine levels also vary across products and may differ from the listed amounts, so that precise assessments of the amount of nicotine being absorbed may not be feasible for the person vaping. Because of the ability of e-cigarettes to provide nicotine, there have been numerous studies that have suggested that e-cigarettes may serve a constructive function in fostering smoking cessation or at least a reduction in the number of cigarettes that are smoked, and may be more effective than other nicotine replacement therapies (Polosa et al. 2011; Siegel et al. 2011; Bullen et al. 2013; Caponnetto et al. 2013; Brown et al. 2014; Wagener et al. 2014). Although some previous evidence has been mixed, the study by Hajek et al. (2019) randomly assigned participants to a nicotine-replacement product or an e-cigarette starter pack and found an 8% higher cigarette abstinence rate after one year for the e-cigarette group.

A new potential risk factor for e-cigarettes emerged in 2019 after a vaping illness crisis emerged, with illness cases reaching a peak in the fall of that year. By the end of 2019, there were 55 deaths and 2651 hospitalizations from illnesses that the CDC termed EVALI, or e-cigarette or vaping product use-associated lung injuries. The rate of vaping illnesses has abated, as the cumulative number of EVALI cases or deaths as of February 4, 2020 was 2758, of which 64 were deaths (Centers for Disease Control and Prevention 2020). The two vaping product ingredients that have been most closely linked to the illnesses are the psychoactive ingredient in marijuana, tetrahydrocannabinol (THC), and vitamin E acetate. Thus far, their presence is correlated with the illness outbreak rather than being an identified causal linkage. For 1090 vaping samples connected to patients, the FDA found that THC was present in most of the samples that were tested (Food and Drug Administration 2020). Moreover, 50% of the THC samples had vitamin E acetate as the diluent, while 29% of the THC samples had other diluents such as medium chain triglycerides. Another FDA analysis of 677 samples linked to 95 patients found that 73% of the vaping illnesses were connected to products containing THC. Of these, 81% had vitamin E acetate as the diluent, and other diluents were present in products, but to a lesser extent. Based on these analyses, the FDA recommends against e-cigarettes containing THC or vitamin E acetate. Public Health England (2019) prohibits the use of THC and vitamin E acetate in vaping liquids and has not had comparable illness incidents.

In the case of conventional cigarettes, the preponderance of the risk is from tobacco rather than additives such as flavor enhancers, which do not affect product riskiness to any consequential extent. The ingredients in e-cigarettes are potentially quite varied. Products are not standardized on a national basis in part because vape shops are permitted to make their own vaping juice, and the market is largely unregulated. England has not experienced a similar vaping illness crisis, but it has more stringent regulation of vaping devices, including limits on nicotine content and prohibitions against certain ingredients in vaping devices.

3 Sample for the 2019 survey

The online survey used in Viscusi (2016) was administered to the GfK Knowledge Panel in 2014. The sample consisted of 1041 adult respondents age 18 and older. The sample will serve as a basis of comparison for the results considered here. The 2019 survey (Vanderbilt IRB number 191999) was administered to the Amazon MTurk sample in late November and early December 2019. The timing of the 2019 survey followed the wave of national publicity regarding vaping-related illnesses and deaths. In addition to this informational event, there has been an increase in vaping rates since the earlier 2014 survey, which also may affect risk beliefs and other attitudes toward the product. The survey duration was about 10 minutes.

As was the case with the 2014 survey, the online 2019 survey was restricted to U.S. citizens, age 18 and above. The majority of the sample—66%—consisted of MTurk Masters, who are experienced survey takers who have demonstrated consistent responses in a broad range of surveys. The sample of 1028 valid responses is summarized in Table 1. Twenty-nine responses were excluded because of a failure to respond to the main questions of interest. The sample size for some variables in Table 1 is sometimes less than 1028 because the survey frequently gave respondents the option of not answering the question if they did not want to disclose personal information such as their income or if they were unwilling to commit to a response to a question. The sample was 56% males, with an average age of 39 and 15 years of education. The 2014 sample was somewhat older, with a mean age of 51, 50% male, and the same average education level as the 2019 sample. The 2019 survey consisted of 19% cigarette smokers, and the 2014 survey had 13% smokers. The average adult smoking rate in the U.S. was 17% in 2014, and had dropped to an all-time low of 14% in 2018. The recent survey slightly oversampled smokers, and the 2014 survey slightly undersampled smokers.

The most notable difference in the sample characteristics was the degree to which the respondent had tried e-cigarettes. For the 2014 adult sample, vaping was a niche activity, as only 12% had tried e-cigarettes. For the more recent and somewhat younger 2019 sample, 34% had tried e-cigarettes. As a consequence, the 2019 survey questions inquiring about the risks and other characteristics of e-cigarettes are less likely to be viewed as a hypothetical exercise and are more likely to draw on personal experiences with e-cigarettes. For the 2019 sample, 13% of respondents indicated that they smoke e-cigarettes either separately or in addition to smoking conventional cigarettes.

All variables other than the regional location variables are based on questions that explicitly elicited the information as part of the survey. The regional variables were constructed based on the latitude and longitude location of the respondent. This information was available for respondents who took the survey using a GPS-enabled device.

The survey included numerous risk awareness and risk belief questions. Awareness of media reports of vaping-related illnesses and deaths was widespread, as 75% of the sample were aware of the news reports regarding the spate of EVALI incidents. The survey included a variety of quantitative and qualitative risk questions about cigarettes and e-cigarettes. These questions are described further below. The response rates to these questions was quite high. The failure of respondents to make an objective assessment of the risks of lung cancer or total mortality from cigarettes or e-cigarettes was quite low, as it never exceeded 0.4% of the sample.

Table 1 Sample characteristics

Variable	Mean	Standard Deviation
Male	0.56	0.50
Nonwhite	0.22	0.41
Education (years)	15.07	1.89
Income (divided by 10,000)	5.01	3.28
Top coded income	0.03	0.17
Age	38.80	11.24
Married	0.38	0.49
Children (under 18)	0.56	0.98
Northeast region	0.21	0.41
South region	0.33	0.47
MTurk Master	0.66	0.47
Smoker	0.19	0.39
Former smoker	0.32	0.47
Nonsmoker	0.81	0.39
Tried e-cigarettes	0.34	0.48
Current e-cigarette user	0.13	0.34
Exclusive e-cigarette user	0.06	0.25
Cigarette lung cancer beliefs	32.49	23.18
Cigarette total mortality beliefs	43.29	25.54
E-cigarette lung cancer beliefs	20.40	21.87
E-cigarette total morality beliefs	27.80	25.30
Saw vaping illness news	0.75	0.43

$N = 1028$

4 Risk beliefs for e-cigarettes and cigarettes

For both cigarettes and e-cigarettes, the survey included objective risk belief questions. The information provided by the survey consequently makes it possible to assess whether risk beliefs are higher or lower than scientists' estimates of the actual risk, thus making it feasible to ascertain whether there is a market failure due to inadequate beliefs regarding the risk. The survey also included qualitative questions for respondents to rate the comparative risks of e-cigarettes and conventional cigarettes. These extensive risk belief questions make it feasible to both compare the risk beliefs for these two products and to analyze whether there is a relationship between risk beliefs for cigarettes and e-cigarettes.

The survey first asked respondents to assess the objective lung cancer and total mortality risks of cigarettes, which was followed by a relative risk belief question comparing cigarette and e-cigarette risk beliefs, and then questions eliciting objective lung cancer risks and total mortality risks for e-cigarettes. The relative risk questions for cigarettes and e-cigarettes were in terms of comparative "risk" rather than the comparative "harm" wording used in the surveys analyzed by Dave et al. (2020), but that wording difference is not likely to be consequential.

The objective risk questions ask people to rate the risk out of a population of 100 users of conventional cigarettes and e-cigarettes. This well-established question framing follows the approach in Viscusi (2016) and in several previous cigarette risk surveys that are reviewed in Viscusi (2002, 2016). Asking people to assess the risk with respect to a denominator of 100 is easily understood and is suitable given the magnitude cigarette risks. The survey first addressed the risks posed by cigarettes with two questions pertaining to lung cancer risks and total mortality risks: i) "Out of every 100 smokers, how many of them do you think will die of lung cancer because they smoke?" and ii) "And out of every 100 cigarette smokers, how many of them do you think will die from lung cancer, heart disease, throat cancer, or any other illness because they smoke?"

The top two rows of Table 2 present the results for these two questions. For the full sample, the lung cancer risk belief probability is 0.33, and for the total mortality risk the assessed probability is 0.43. These results are lower than those reported in Viscusi (2016), which had a different sample. Smokers have lower risk beliefs than nonsmokers, which is expected since people with lower risk beliefs should be more willing to sort themselves into smoking behavior. For both smokers and nonsmokers, the perceived risks greatly exceed scientists' estimates of the actual risk levels for smoking. The estimated total lifetime risks from smoking are 0.08 for lung cancer and 0.26 for total smoking mortality, each of which is below the average risk beliefs for cigarettes in this sample.[1]

Before introducing the counterpart questions for e-cigarettes, the survey included a transition question intended to introduce e-cigarettes and to set the context for the subsequent sections: "Recently there have been sales of electronic cigarettes known as e-cigarettes. These are battery-powered devices that may look like cigarettes but don't burn tobacco. Instead, these e-cigarettes vaporize a fluid that included nicotine. Smoking e-cigarettes is often called vaping. Do you know anyone who ever smoked an e-cigarette?" Overall, 77% of the sample knew e-cigarette smokers.

After asking respondents a comparative cigarette and e-cigarette risk question that will be discussed below, the survey repeated objective risk assessment questions for e-cigarettes that followed the structure of the conventional cigarette questions: i) "Out of 100 people who smoke only e-cigarettes but do so just as often as they would conventional cigarettes, how many of them do you think will die from lung cancer because they smoke?" and ii) "And out of every 100 e-cigarette smokers who smoke just as often as smokers of conventional cigarettes, how many do you think will die from lung cancer, heart disease, throat cancer, or any other illness because they smoke?"

The e-cigarette risk responses in the bottom two rows of Table 2 indicate an average risk belief of 0.20 for lung cancer and 0.28 for the total mortality risk. These values are quite similar for smokers and nonsmokers of conventional cigarettes. That the assessed risks are so high and far in excess of the actual risk levels is not entirely surprising given that U.S. public health officials and many public health advocates do not

[1] These risk estimates were calculated based on mortality estimates drawn from the U.S. Surgeon General in conjunction with information on the size of the smoking population. The calculations are described in Viscusi (2016). Based on earlier governmental estimates of the risk levels, the estimated mortality rate from lung cancer is 0.06 and for total mortality it is 0.18. See Viscusi (1992, 2002, 2016).

Table 2 Risk perceptions out of 100 smokers for cigarettes and e-cigarettes

	Full sample	Smokers	Nonsmokers
Cigarette risk beliefs			
Lung cancer	32.5 (23.2)	29.2 (23.2)	33.3 (23.1)
Total mortality	43.3 (25.5)	38.6 (24.2)	44.4 (25.8)
E-cigarette risk beliefs			
Lung cancer	20.4 (21.8)	20.2 (23.5)	20.5 (21.5)
Total mortality	27.8 (25.3)	26.2 (25.0)	28.2 (25.4)

$N = 1024$ (cigarette lung cancer, cigarette total mortality, e-cigarette total mortality) and $N = 1022$ (e-cigarette lung cancers

distinguish any differential level of riskiness for conventional cigarettes and e-cigarettes.

To analyze the determinants of risk beliefs, it is useful to conceptualize the consumer's task using a Bayesian model developed in Viscusi (2016) in which people draw on available sources of information about e-cigarettes and smoking activities more generally in forming their risk assessments. As in Viscusi (2016), I model cigarette and e-cigarette risk beliefs using a beta distribution. This distribution is quite flexible, as it can assume a variety of skewed and symmetric shapes.[2] The exposition of the model is in terms of the subjective assessment of the probability of death. The empirical analysis considers the perceived probability of death from lung cancer and from all causes, both for cigarettes and e-cigarettes. Suppose that the individual has an assessed probability of death associated with conventional cigarettes given by p, and has an assessed probability of death for e-cigarettes equal to s. In forming their assessed risk s for e-cigarettes, people can use a variety of information sources, including what they have learned about the risks of conventional cigarettes, given by p, as well as risks implied by all other information that they received, which I categorize by the probability value q. In the absence of new information about e-cigarettes and how they differ from conventional cigarettes, many people might treat the value of p as their prior risk beliefs for e-cigarettes.

Based on the beta distribution formulation, the posterior risk s for e-cigarettes is a linear function of the perceived conventional cigarette risk p and the risk q implied by other information. Each of these components has an informational weight that governs the role of these beliefs in influencing e-cigarette risk assessments. Let the informational weight on p be ψ_0 and the weight on q be γ_0. In terms of the model, one can view ψ_0 and γ_0 as being equivalent to the number of draws from a Bernoulli urn corresponding to the total amount of information the person has about conventional cigarette risk p and the risk q implied by other available information. The perceived risk s from e-cigarettes consequently equals

[2] The particular parameterization of the beta distribution was introduced in Viscusi and O'Connor (1984) to analyze processing of chemical labeling policies. It has also been used by Viscusi (1991, 1992, 2016) to analyze smoking-related issues.

$$s = \frac{\psi_0 p + \gamma_0 q}{\psi_0 + \gamma_0}. \quad (1)$$

It is helpful to rewrite Eq. 1 in terms of the fraction of the total informational content associated with p and q, which is given by $\psi = \psi_0/(\psi_0 + \gamma_0)$ and $\gamma_0 = \gamma_0/(\psi_0 + \gamma_0)$. Unlike the information weights, which cannot be estimated empirically, it is feasible to estimate the fraction of the information content associated with each source through an equation of the form

$$s = \psi p + \gamma q. \quad (2)$$

The e-cigarette risk belief s is a weighted average of the perceived cigarettes risk s, weighted by the fraction of the total information content associated with cigarette risk beliefs, plus implied risk q of e-cigarettes based on other risk information, which is weighted by the fraction of information associated with this value. Respondents perceive the risk of e-cigarettes to be less than that of conventional cigarettes if

$$s = \psi p + \gamma q < p, \quad (3)$$

or if $q < p$. The survey does not provide information on the value of q, so that it will be captured by the inclusion of a variety of other variables to reflect individual characteristics and experiences. For example, younger respondents are more likely to be informed of the characteristics of e-cigarettes compared to conventional cigarettes.

Conventional cigarettes and e-cigarettes differ not only in their risk levels but also in their consumption experience, as smoking and vaping are different. Suppose that the risk probabilities pertain to the risk of death and that there is only a single-period decision. If u is the utility of smoking conventional cigarettes and v is the utility of smoking e-cigarettes, the expected utility of smoking will exceed that of conventional cigarettes if

$$(1-s)v > (1-p)u, \quad (4)$$

or

$$\frac{u}{v} < \frac{(1\text{-}s)}{(1\text{-}p)}. \quad (5)$$

People will prefer e-cigarettes if the relative utility of the two products is below the ratio of the expected probabilities of survival.

Column 1 of Table 3 presents regression estimates for e-cigarette lung cancer risk beliefs, which are a function of cigarette lung cancer risk beliefs and a variety of demographic characteristics, and column 2 of Table 3 presents analogous regression results for e-cigarette total mortality risk beliefs as a function of the total mortality risk from cigarettes. Each of these cigarette variables has a powerful relationship with e-cigarette risk beliefs, with coefficients of 0.61 for lung cancer and 0.63 for the total mortality risk. These results are consistent with people using cigarette risk assessments

as their prior risk beliefs for e-cigarettes and then discounting this value by about one-third. The extent of the linkage is similar to that in the 2014 survey, but the degree of passthrough in the 2019 survey is slightly lower, as the 2014 cigarette risk coefficients are 0.68 for lung cancer and 0.70 for total mortality risk. Having seen media reports of vaping-related illnesses has no statistically significant effect on risk beliefs for either lung cancer or total mortality.

Several demographic variables are correlated with risk beliefs in a consistent manner for the two risks. E-cigarette risk beliefs are higher for nonwhites and respondents who are married, and are lower for males and former smokers, many of whom may smoke e-cigarettes. The negative coefficient for MTurk Masters may reflect a greater ability of experienced survey takers to make quantitative risk assessments that more accurately reflect the available scientific evidence.

The survey also included a relative risk comparison question: "How would you compare the risks of smoking a typical e-cigarette to smoking a conventional cigarette, assuming that the person smokes just as often?" They were given the following options: "much less risky than conventional cigarettes, somewhat less risky than conventional cigarettes, just as risky as conventional cigarettes, somewhat more risky than conventional cigarettes, much more risky than conventional cigarettes."

Table 4 presents the responses to this question for the 2014 sample in column 1. The 2019 sample results in the remaining columns pertain to the full sample, those who have tried e-cigarettes, and those who have not tried e-cigarettes. For the full sample results, there has been a decline in the fraction who believe that e-cigarettes are just as risky as conventional cigarettes. This amount has dropped from 0.44 to 0.34.

As the percentage of the population who has tried e-cigarettes has increased, the share of the population that does not equate e-cigarette risks and conventional cigarette

Table 3 E-cigarette risk belief regressions

	Lung cancer	Total mortality
Cigarette risk beliefs	0.609*** (0.031)	0.632*** (0.027)
Saw vaping illness news	−1.231 (1.180)	−1.795 (1.319)
Male	−2.990*** (1.054)	−4.196*** (1.254)
Nonwhite	2.984** (1.414)	3.047** (1.521)
Education	−0.075 (0.291)	0.090 (0.326)
Income (divided by 10,000)	0.379** (0.169)	0.276 (0.188)
Age	0.005 (0.051)	0.010 (0.055)
Married	3.643*** (1.319)	4.534*** (1.504)
Children	−0.213 (0.682)	0.768 (0.811)
Smoker	1.283 (1.577)	0.407 (1.721)
Former smoker	−2.446*** (1.192)	−3.064** (1.424)
MTurk Master	−3.623*** (1.148)	−4.860*** (1.346)
R^2	0.45	0.43

$N = 1022$ for lung cancer regression and $N = 1024$ for total mortality risks regression. Equations also include indicator variables for region, missing data on variables, and top coded income. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Risk beliefs for e-cigarettes compared to conventional cigarettes

		Fraction of sample in category in 2019 survey		
	2014 survey	Full sample	Have tried e-cigarettes	Have not tried e-cigarettes
Much less risky	0.14	0.17	0.31	0.09
Somewhat less risky	0.38	0.35	0.31	0.38
Just as risky	0.44	0.34	0.20	0.41
Somewhat more risky	0.02	0.11	0.14	0.09
Much more risky	0.02	0.04	0.04	0.04

$N = 1028$ for 2019 survey and $N = 1041$ for 2014 survey

risks has declined and offset any impact of the vaping illness crisis. The next most prominent response was for people who view e-cigarettes as somewhat less risky. If we pool the "somewhat less risky" and "much less risky" results, then 52% of the sample in 2014 and in 2019 view e-cigarettes as less risky to some degree. There has, however, been an increase in the percentage who view e-cigarettes as being somewhat more risky or much more risky, as that percentage has gone from 4% to 15% across the two survey periods. Particularly striking is that 18% of those who have tried e-cigarettes now view e-cigarettes as more risky than conventional cigarettes. By way of comparison, across the two samples that they analyze, Dave et al. (2020) find that 22% of respondents view cigarettes as being "more harmful" than conventional cigarettes. My finding of somewhat lower comparative "risk" beliefs may arise because my survey elicited the objective cigarette risk assessments for cigarettes before inquiring about relative risk beliefs.

The relative risk belief responses are correlated with the risk beliefs for cigarettes and e-cigarettes in the expected manner. Table 5 presents the ordered probit results in which the dependent variable is the ordinal response to the relative risk question, where higher values correspond to increasing degrees of relative riskiness of e-cigarettes, i.e., much more risky = 5,…, much less risky = 1. Column 1 of Table 5 presents the estimates for the model in which lung cancer risks for cigarettes and e-cigarettes are used to predict the relative risk values, and column 2 presents results based on the total mortality risks for cigarettes and e-cigarettes. In each instance, higher e-cigarette risk assessments lead the respondent to believe that e-cigarettes are riskier, and higher risk assessments for conventional cigarettes make respondents less likely to view e-cigarette risks as being greater. These coefficients are strongly significant. In terms of magnitude, the e-cigarette risk beliefs have almost double the impact on the relative risk rating than do cigarette risk beliefs even though both are presumably equally pertinent in assessing whether one risk exceeds the other. When considering the risk comparison, the risk of the new product plays a more prominent role and is the focus of respondents' concerns. These results also provide a consistency check on the results in that the relative risk responses perform in the expected manner given the respondents' assessments of each of the component risks.

The regressions in Table 5 also control for a detailed set of personal characteristics. The most interesting of these variables from the standpoint of the risk information

Table 5 Ordered probit regressions for e-cigarette risks compared with cigarette risks

	Lung cancer	Total mortality
Cigarette risk beliefs	−0.022*** (0.003)	−0.024*** (0.002)
E-cigarette risk beliefs	0.047*** (0.004)	0.044*** (0.033)
Saw vaping illness news	−0.031 (0.078)	−0.034 (0.084)
Male	−0.171** (0.073)	−0.147** (0.073)
Nonwhite	0.137 (0.087)	0.161* (0.086)
Education	0.028 (0.020)	0.016 (0.020)
Income (divided by 10,000)	−0.028** (0.012)	−0.013 (0.011)
Age	0.002 (0.003)	0.001 (0.004)
Married	0.048 (0.094)	0.004 (0.089)
Children	0.135*** (0.040)	0.099** (0.040)
Smoker	−0.071 (0.105)	−0.024 (0.108)
Former smoker	−0.171** (0.076)	−0.155** (0.078)
MTurk Master	−0.266*** (0.078)	−0.207*** (0.078)
Pseudo R^2	0.18	−0.19

$N = 1022$ for lung cancer regression and $N = 1024$ for total mortality risks regression. Equations also include indicator variables for region, missing data on variables, and top coded income. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

environment is whether the respondent has seen news reports about the vaping illness incidents. The coefficient for this variable is not statistically significant, perhaps in part because of the widespread awareness of the reports in this sample. Dave et al. (2020) found that there was an increased perception of the harmfulness of vaping after the EVALI crisis, so that the risk shock may have been influential though not correlated with whether the respondent reports awareness of the media reports. The relative risk beliefs concerning e-cigarettes are particularly high for respondents who have children under the age of 18. The broad policy-related concerns regarding the risks of e-cigarettes to younger users of the product are reflected in the risk assessments by the parents. The results in Table 5 are quite robust with respect to the exclusion of the smoking status variables (regressions not reported but the results parallel those here and in Viscusi (2016)).

5 Nicotine and the difficulty of quitting

In addition to the health risks associated with cigarettes related to exposures such as potential carcinogens, there also may be health-related concerns relating to addiction. The presence of nicotine in e-cigarettes is not an intrinsic characteristic of the product, as is the case with conventional cigarettes that burn tobacco. Rather, there is leeway to include no nicotine at all or to manipulate the nicotine content to exceed that in cigarettes. Some jurisdictions such as the U.K. impose upper limits on this discretion with respect to the nicotine concentration. For many consumers who are interested in quitting smoking or reducing smoking rates, the presence of nicotine is a valued

ingredient to facilitate the use of e-cigarettes as a substitute for other possible nicotine delivery systems such as nicotine patches. Because a principal distinguishing characteristic of e-cigarettes is their lower risk level, not their lack of nicotine, one would expect any comparison of e-cigarettes and conventional cigarettes to be closer on the nicotine/quitting dimensions than with respect to risk levels.

The survey included two principal questions regarding the nicotine levels and difficulty of quitting e-cigarettes. The nicotine question asked respondents to compare the nicotine levels in e-cigarettes and conventional cigarettes: "How would you compare the levels of nicotine in e-cigarettes to conventional cigarettes?" The options they considered were: "much less nicotine than conventional cigarettes, somewhat less nicotine than conventional cigarettes, just as much nicotine as conventional cigarettes, somewhat more nicotine than conventional cigarettes, much more nicotine than conventional cigarettes." The distribution of responses in Table 6 indicate that for the 2014 survey and all sample groups in the 2019 survey that just over half of all respondents view the nicotine levels of e-cigarettes to be the same as for conventional cigarettes.

There has, however, been some evident change in the responses that indicate a risk difference. Whereas in 2014, 9% of the respondents viewed e-cigarettes as having somewhat more or much more nicotine and 38% viewed the nicotine levels as having somewhat less or much less nicotine, by 2019 the distribution was quite symmetric, as 23% viewed e-cigarettes as having somewhat more or much more nicotine, and 23% viewed e-cigarettes as having somewhat less or much less nicotine. On balance, consumers now equate the nicotine levels of e-cigarettes and conventional cigarettes rather than believing the e-cigarettes provide a nicotine reduction. Those who have tried e-cigarettes are more likely to indicate that the levels of e-cigarette nicotine are higher.

The question for the relative difficulty of quitting cigarettes has a similar structure: "How hard is it to quit e-cigarettes as compared to conventional cigarettes?" The response options were: "much less difficult to quit than conventional cigarettes, somewhat less difficult to quit than conventional cigarettes, just as difficult to quit as conventional cigarettes, somewhat more difficult to quit than conventional cigarettes, and much more difficult to quit than conventional cigarettes." Given the responses to the comparative nicotine question in which respondents tended to believe that e-cigarettes and conventional cigarettes are comparable in terms of nicotine, if people understand the linkage between nicotine levels and quitting difficulty, one would expect to find a similar parallel in the quitting difficulty question.

Table 6 Perception of nicotine for e-cigarettes compared to conventional cigarettes

		Fraction of sample in category in 2019 Survey		
	2014 Survey	Full sample	Have tried e-cigarettes	Have not tried e-cigarettes
Much less nicotine	0.09	0.04	0.05	0.04
Somewhat less nicotine	0.29	0.19	0.16	0.21
Just as much nicotine	0.53	0.54	0.52	0.55
Somewhat more nicotine	0.07	0.18	0.20	0.17
Much more nicotine	0.02	0.05	0.07	0.03

$N = 1028$ for 2019 survey and $N = 1041$ for 2014 survey

The results in Table 7 for quitting difficulty indicate even stronger equivalence between e-cigarettes and conventional cigarettes than for nicotine levels. The percentage who view both products as just as difficult to quit was 64% in 2014 and 59% in 2019. Very few people believe that e-cigarettes are more difficult to quit than conventional cigarettes. In 2014 only 4% of the sample were in the two more difficult to quit categories, and in 2019 this figure had risen to 11%. For every group in Table 7, the combined percentage who view e-cigarettes in the two less difficult to quit categories is greater than the combined percentage in the two more difficult to quit categories. Thus, while the middle category of equivalent difficulty of quitting is the most dominant response, for those who do not view the quitting difficulty as equivalent, the distribution of responses is not symmetric.

To explore the relationship between the perception of the difficulty of quitting and assessments of nicotine content, Table 8 reports regression results in which the dependent variable is the difficulty of quitting, where these variables are coded as much more difficult to quit = 5,…, much less difficult to quit = 1. The omitted nicotine category variable is the middle equal levels of nicotine level group. The nicotine perception variables are all strongly statistically significant and have coefficients that both have the expected signs and follow reasonable orders of magnitude. The largest coefficients for the nicotine variables are the negative coefficient for much less nicotine and the positive coefficient for much more nicotine.

Of the other variables included in the equation, the result of greatest interest is the significant negative coefficient for having seen media coverage of vaping illnesses and deaths. There is no reason to believe that adverse vaping illness events are likely to make people view e-cigarettes more favorably from the standpoint of the difficulty of quitting the product. It is likely that those who saw the vaping illness media coverage are better informed more generally of the characteristics of e-cigarettes, believing that they are less difficult to quit than conventional cigarettes.

6 Why people smoke e-cigarettes

Marketing studies of cigarette brand choice frequently ask consumers why they smoke particular brands. The overwhelming influences are taste and price. Although such survey responses are not causal estimates of impacts, they illuminate the factors that are

Table 7 Perception of difficulty of quitting e-cigarettes compared to conventional cigarettes

		Fraction of sample in category 2019 Survey		
	2014 Survey	Full sample	Have tried e-cigarettes	Have not tried e-cigarettes
Much more difficult	0.02	0.04	0.04	0.03
Somewhat more difficult	0.02	0.07	0.08	0.07
Just as difficult	0.64	0.59	0.49	0.63
Somewhat less difficult	0.23	0.24	0.29	0.22
Much less difficult	0.09	0.07	0.10	0.05

$N = 1028$ for 2019 survey and $N = 1041$ for 2014 survey

Table 8 Ordered probit regressions for difficulty of quitting e-cigarettes compared to cigarettes

Much less nicotine	−1.385*** (0.212)
Somewhat less nicotine	−0.693*** (0.094)
Somewhat more nicotine	0.816*** (0.114)
Much more nicotine	1.212*** (0.221)
Saw vaping illness news	−0.194** (0.085)
Male	−0.025 (0.074)
Nonwhite	0.103 (0.093)
Education	0.032 (0.020)
Income (divided by 10,000)	0.010 (0.012)
Age	0.006* (0.003)
Married	0.122 (0.092)
Children	0.005 (0.041)
Smoker	−0.211** (0.099)
Former smoker	−0.157* (0.084)
MTurk Master	−0.085 (0.081)
Pseudo R^2	0.12

$N = 1028$. Equation also includes indicator variables for region, missing data on variables, and top coded income. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

prominent concerns to consumers. If people view e-cigarettes as simply another cigarette brand, then one would expect taste and price to be dominant concerns driving stated reasons for vaping. If e-cigarettes are viewed as a different type of smoking product, then one would expect other factors to be influential.

To explore comparable rationales for why people smoke e-cigarettes, the 2019 survey inquired about a series of possible reasons for smoking e-cigarettes that are listed in Table 9. The sample for this question consists of the 136 e-cigarettes smokers. The dominant concerns are risk-related. For 44% of the respondents, the reason for smoking e-cigarettes is that they are trying to quit conventional cigarettes, and 29% indicate that they are trying to reduce the amount of conventional cigarettes that they smoke. Two of the rationales listed in Table 9 pertain to smoking-related externalities. Exposing others to environmental tobacco smoke is likely to be a concern of the 32% who smoke e-cigarettes because of convenience in that e-cigarettes can be smoked in more places. This convenience factor may in part reflect environmental tobacco smoke limitations that apply to cigarette smoke but not to vaping emissions. More directly related to the concern with exposure of others is that 16% of respondents prefer e-cigarettes because they do not want to expose people nearby to smoke. Only 21% indicate that e-cigarettes have a better flavor than conventional cigarettes, and 25% believe that e-cigarettes are less expensive than conventional cigarettes. A minority of e-cigarette smokers mention the two traditional drivers of cigarette brand choice, taste and price.

Risk-related concerns play a prominent role in determining whether people have used or currently use e-cigarettes. Consider the probit regressions in Table 10 for which the 0–1 dependent variables for the three columns are whether the respondent has tried

e-cigarettes, whether the respondent is a current user of e-cigarettes, and whether the respondent vapes exclusively and does not smoke conventional cigarettes. For each of these usage variables, Table 10 reports three different sets of regression results, focusing only on the risk-related variables. The first set of regression results in Table 10 includes the relative aspects of e-cigarettes as compared to conventional cigarettes. For purposes of this analysis, the much less risky and somewhat less risky responses are combined into a single less risky category, and similarly the much less nicotine and somewhat less nicotine responses are combined. The omitted groups that serve as the basis for comparison are those who believe that e-cigarettes are just as risky, somewhat more risky, and much more risky, and similarly for the nicotine omitted groups. The relative nicotine perception variables are never statistically significant, which is consistent with people not believing that e-cigarettes serve as a mechanism for reducing nicotine levels. However, perceiving e-cigarettes as less risky increases the probability of trying e-cigarettes by 0.21, increases the probability of being a current user of e-cigarettes by 0.07, and increases the probability of vaping exclusively but not smoking conventional cigarettes by 0.05. Because only 48% of the sample would be involved in shifting relative risk beliefs from just as risky and more risky to the less risky group, the average effects of more accurate risk beliefs on vaping rates must be weighted by this amount. The overall impact on vaping if all people in the sample believed that e-cigarettes were less risky would be to increase the sample average rate of trying e-cigarettes by 10%, increase the rate of current e-cigarette usage by 3%, and increase the exclusive use of e-cigarettes by 2%.

The next panel of estimates reports the results when the risk variables are those pertaining to the perceived lung cancer risks of the two products. Higher risk beliefs for cigarettes have a statistically significant positive effect on all three e-cigarette variables, and the perceived e-cigarette risk variables have a consistently significant negative effect. The absolute magnitude of the coefficient for e-cigarettes is greater than for conventional cigarettes as consumers place a greater weight on e-cigarette risk beliefs in making their decision to use e-cigarettes. To get a sense of the magnitude of the effect of the e-cigarette lung cancer risk belief coefficients, consider the effect of the mean value of the risk belief variable, or the effect if e-cigarette lung cancer risk beliefs were zero. An assumption that e-cigarettes reduce the lung cancer risks to zero is not appreciably different than the results implied by the medical literature, and making this assumption simplifies the calculations. Reducing e-cigarette lung cancer risk beliefs by this amount would increase the probability of trying e-cigarettes by 0.12, increase the

Table 9 Why people smoke e-cigarettes (percentage)

Trying to quit conventional cigarettes	44
Trying to reduce amount of conventional cigarettes I smoke	29
Convenience, e-cigarettes can be smoked in more places	32
Prefer not to expose people nearby to smoke	16
Better flavor than conventional cigarettes	21
Less expensive than conventional cigarettes	25

$N = 136$

Table 10 Probit regressions for use of e-cigarettes

	Tried e-cigarettes	Current e-cigarette user	Exclusive e-cigarette user
Compared to cigarettes			
Less risky	0.205*** (0.035)	0.070*** (0.015)	0.047*** (0.009)
Less nicotine	−0.038 (0.038)	−0.007 (0.018)	−0.007 (0.010)
Lung cancer beliefs			
Cigarettes	2.86E-3*** (0.91E-3)	1.12E-3*** (0.39E-3)	0.79E-3*** (0.26E-3)
E-cigarettes	−6.12E-3*** (0.98E-3)	−1.81E-3*** (0.46E-3)	−1.34E-3*** (0.42E-3)
Mortality risk beliefs			
Cigarettes	2.89E-3*** (0.80E-3)	0.87E-3*** (0.37E-3)	0.68E-3*** (0.20E-3)
E-cigarettes	−5.06E-3*** (0.84E-3)	−1.62E-3*** (0.40E-3)	−1.25E-3*** (0.26E-3)

$N = 1028$, 1022, and 1024 in these regressions. Coefficients have been transformed to correspond to marginal effects. Equations also include age, male, nonwhite, education, income, top coded income, married, children, smoker, former smoker, MTurk Master, and indicator variables for three regions and if missing location data on variables. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

probability of currently using e-cigarettes by 0.04, and increase the probability of being an exclusive user of e-cigarettes by 0.03.

The pattern of results for the final panel of estimates for overall mortality risk beliefs is similar, with higher cigarette risk beliefs increasing each of the three e-cigarette usage variables and higher e-cigarette risk beliefs reducing the three e-cigarette usage variables. The mean effect of the e-cigarette mortality risk beliefs variable is to reduce the probability of trying e-cigarettes by 0.14, reducing the probability of currently using e-cigarettes by 0.05, and reducing the probability of vaping exclusively by 0.03. As in the case of the relative risk belief variables and the lung cancer risk belief variables, increased perception of the riskiness of e-cigarettes reduces all three different measures of usage of e-cigarettes. More people would use e-cigarettes if they perceived that the risks were lower.

7 Conclusion

The public recognizes that e-cigarettes are safer than conventional cigarettes. This belief is reasonable, but most people substantially underestimate the risk reduction that can be achieved by switching to e-cigarettes. By any objective standard, e-cigarettes are a product that poses considerably lower health risks than conventional cigarettes. However, public health officials in the U.S. have made few distinctions regarding the relative safety of e-cigarettes and conventional cigarettes. Not surprisingly, the American public consequently views e-cigarettes as much riskier than current evidence suggests them to be. E-cigarette risk beliefs are strongly correlated with risk beliefs for conventional cigarettes. The estimates are consistent with a Bayesian model in which people place a weight of 60% or more on their assessed risk levels for conventional cigarettes in assessing the risks of e-cigarettes. Based on the conclusions reached by Public Health England, this weight should be 5% or less. In effect, the American public is too wed to cigarette risk beliefs in forming their e-cigarette risk assessments.

Although the risk beliefs regarding e-cigarettes are overly alarmist, the manner in which people subsequently incorporate these risk beliefs in their choices is consistent with economic predictions. Consumers correctly do not perceive that e-cigarettes are a mechanism to avoid nicotine, and perceptions of nicotine are not significantly correlated with the decision to vape, even for those who believe that the nicotine levels for e-cigarettes are lower. The assessments of the risk of e-cigarettes, conventional cigarettes, and the relation between these values affect the likelihood that a person tries e-cigarettes, currently uses e-cigarettes, or vapes exclusively rather than smoking cigarettes. Risk factors also figure prominently in consumers' views of their reasons for vaping. Concern about the risks of conventional cigarettes to oneself and others are much more prominent influences than taste and price in the reported reasons for why people vape e-cigarettes.

Awareness of the media coverage of vaping illnesses and deaths in 2019 did not have an apparent, substantial effect on risk beliefs. People have higher risk beliefs than they did in 2014, but they still view e-cigarettes as safer than conventional cigarettes. However, the emergence of these illnesses highlights some of the potential hazards of e-cigarettes that can arise in a largely unregulated market in which the ingredients and nicotine content of vaping products are unregulated. While the efforts to ban e-cigarettes appear to be misdirected given their comparative safety, there is a rationale for regulation to limit the nicotine concentration and, more importantly, to limit the composition of vaping liquids. In that respect, e-cigarettes differ from conventional cigarettes, for which the dominant inhalation experience is smoke from burning tobacco. The presence or exclusion of flavor enhancers and other chemicals in conventional cigarettes does not alter their risk levels appreciably. In contrast, the chemicals used in vaping liquids may potentially create new, possibly substantial risks so long as these ingredients remain unregulated. The absence of U.S. regulation on these dimensions may be reducing the overall desirability of a product that otherwise may be a viable, lower risk alternative to conventional cigarettes.

References

Brown, J., Beard, E., Kotz, D., Michie, S., & West, R. (2014). Real-world effectiveness of e-cigarettes when used to aid smoking cessation: A cross-sectional population study. *Addiction, 109*(9), 1531–1540.

Bullen, C., Howe, C., Laugesen, M., McRobbie, H., Parag, V., Williman, J., & Walker, N. (2013). Electronic cigarettes for smoking cessation: A randomised control trial. *The Lancet, 382*(9905), 1629–1637.

Caponnetto, P., Campagna, D., Cibella, F., Morjaria, J. B., Caruso, M., Russo, C., & Polosa, R. (2013). Efficiency and safety of an electronic cigarette (ECLAT) as tobacco cigarettes substitute: A prospective 12-month randomized control design study. *PLoS One, 8*(6), e66317.

Centers for Disease Control. (2020). Outbreak of lung injury associated with use of e-cigarette, or vaping, products. Cdc.gov/tobacco/basic-infromation/e-cigarettes/severe-lung-disease.html. Accessed 2 Mar 2020.

Dave, D., Dench, D., Kenkel, D., Mathios, A., & Wang, H. (2020). News that takes your breath away: Risk perceptions during an outbreak of vaping-related injuries. *Journal of Risk and Uncertainty, 60*(3).

Ellsberg, D. (1961). Risk, ambiguity, and the Savage axioms. *Quarterly Journal of Economics, 75*(4), 643–669.

Farsalinos, K. E., & Polosa, R. (2014). Safety evaluation and risk assessment of electronic cigarettes as tobacco substitutes: A systematic review. *Therapeutic Advances in Drug Safety, 5*(2), 67–86.

Fischhoff, B., Lichtenstein, S., Slovic, P., Derby, S., & Keeney, R. L. (1981). *Acceptable risk*. Cambridge: Cambridge University Press.

Food and Drug Administration. (2020). Lung injuries associated with vaping products. Fda.gov/news-evnets/public-health-focus/lung-injuries-associated-use-vaping-products. Accessed 2 Mar 2020.

Hajek, P., Phillips-Waller, A., Przulj, D., Pesola, F., Myers Smith, K., Bisal, N., et al. (2019). A randomized trial of e-cigarettes versus nicotine-replacement therapy. *New England Journal of Medicine, 360*(7), 629–637.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 47*(2), 263–291.

McAuley, T. R., Hopke, P. K., Zhao, J., & Babaian, S. (2012). Comparison of the effects of e-cigarette vapor and cigarette smoke on indoor air quality. *Inhalation Toxicology, 24*(12), 850–857.

National Academies of Sciences, Engineering, and Medicine. (2018). *Public health consequences of e-cigarettes*. Washington, D.C.: National Academies Press.

Polosa, R., Caponnetto, P., Morjaria, J. B., Papale, G., Campagna, D., & Russo, C. (2011). Effect of an electronic nicotine delivery device (e-cigarette) on smoking reduction and cessation: A prospective 6-month pilot study. *BMC Public Health, 11*(1), 786. http://www.biomedcentral.com/1471-2458/11/786.

Public Health England. (2015). Press Release. E-cigarettes are around 95% less harmful than tobacco estimates landmark review. www.gov.uk/government/news/e-cigarettes-around-95-less-harmful-than-tobacco-estimates-landmark-review.

Public Health England. (2018). Evidence review of e-cigarettes and heated tobacco products. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/684963/Evidence_review_of_ecigarettes_and_heated_tobacco_products_2018.pdf. Accessed 24 Feb 2020.

Public Health England. (2019). Vaping and lung disease in the U.S.: PHE's advice. https://publichealthmatters.blog.gov.uk/2019/10/29/vapiong-and-lung-disease-in-the-us-phes-advice/. Accessed 24 Feb 2020.

Siegel, M. B., Tanwan, K. L., & Wood, K. S. (2011). Electronic cigarettes as a smoking cessation tool. *American Journal of Preventive Medicine, 40*(4), 472–475.

Stephens, W. E. (2018). Comparing the cancer potencies of emissions from vapourised nicotine products including e-cigarettes with those of tobacco smoke. *Tobacco Control, 27*(1), 10–17.

U.S. Department of Health and Human Services. (2014). *The health consequences of smoking—50 years of progress: A report of the surgeon general*. Atlanta: U.S. Department of Health and Human Services.

Viscusi, W. K. (1991). Age variations in risk perceptions and smoking decisions. *Review of Economics and Statistics, 73*(4), 577–588.

Viscusi, W. K. (1992). *Smoking: Making the risky decision*. New York: Oxford University Press.

Viscusi, W. K. (1998). *Rational risk policy*. Oxford: Oxford University Press.

Viscusi, W. K. (2002). *Smoke-filled rooms: A postmortem on the tobacco deal*. Chicago: University of Chicago Press.

Viscusi, W. K. (2016). Risk beliefs and preferences for e-cigarettes. *American Journal of Health Economics, 2*(2), 213–240.

Viscusi, W. K., & DeAngelis, S. (2018). Decision irrationalities involving deadly risks. *Journal of Risk and Uncertainty, 57*(3), 225–252.

Viscusi, W. K., & O'Connor, C. J. (1984). Adaptive responses to chemical labeling: Are workers Bayesian decision makers? *American Economic Review, 74*(5), 942–956.

Wagener, T. L., Meier, E., Hale, J. J., Oliver, E. R., Warner, M. L., Driskill, L. M., Gillaspy, S. R., Siegel, M. B., & Foster, S. (2014). Pilot investigation of changes in readiness and confidence to quit smoking after e-cigarette experimentation and 1 week of use. *Nicotine Tobacco Research, 16*(1), 108–114.