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Estimating Cross-Price Elasticity of E-Cigarettes Using a Simulated Demand Procedure

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Abstract

Introduction: Our goal was to measure the cross-price elasticity of electronic cigarettes (e-cigarettes) and simulated demand for tobacco cigarettes both in the presence and absence of e-cigarette availability.

Method: A sample of New Zealand smokers (*N* = 210) completed a Cigarette Purchase Task to indicate their demand for tobacco at a range of prices. They sampled an e-cigarette and rated it and their own-brand tobacco for favorability, and indicated how many e-cigarettes and regular cigarettes they would purchase at 0.5×, 1×, and 2× the current market price for regular cigarettes, assuming that the price of e-cigarettes remained constant.

Results: Cross-price elasticity for e-cigarettes was estimated as 0.16, and was significantly positive, indicating that e-cigarettes were partially substitutable for regular cigarettes. Simulated demand for regular cigarettes at current market prices decreased by 42.8% when e-cigarettes were available, and e-cigarettes were rated 81% as favorably as own-brand tobacco. However when cigarettes cost 2× the current market price, significantly more smokers said they would quit (50.2%) if e-cigarettes were not available than if they were available (30.0%).

Conclusion: Results show that e-cigarettes are potentially substitutable for regular cigarettes and their availability will reduce tobacco consumption. However, e-cigarettes may discourage smokers from quitting entirely as cigarette price increases, so policy makers should consider maintaining a constant relative price differential between e-cigarettes and tobacco cigarettes.

Introduction

Nicotine electronic cigarettes (e-cigarettes) were introduced by the Chinese company Ruyan in 2004 and have since become an increasingly popular and widely-marketed product. They consist of a plastic or metal tube containing a battery, usually with a LED tip, and a cartomizer containing a heating element, a liquid (usually containing nicotine but no tobacco) creating an aerosol for inhalation, and a mouthpiece. Because users' behaviors with e-cigarettes mimic those of regular cigarettes very closely, they have been advocated as a safer alternative for smokers and an aid for smoking cessation.[1] However, e-cigarettes have been criticized as potentially harmful given concerns about the long-term consequences of inhaling propylene glycol (used as a humectant in many e-cigarettes) and nicotine consumption, and that e-cigarettes could serve as a "gateway" product, particularly for younger users, leading to eventual tobacco addiction.[2]

There is evidence that e-cigarettes may be at least as effective as other nicotine replacement therapy devices in terms of nicotine delivery and alleviation of withdrawal symptoms. Vansickel and Eissenberg[3] found that elevated plasma nicotine levels for e-cigarette users were detectable within 5 min of the first puff, and increased consistently during a 1-hr *ad libitum* puffing period. Bullen et al.[4] showed that a first-generation e-cigarette (the Ruyan V8) reduced cravings after overnight abstinence in a single-blind randomized study. Bullen et al.[5] conducted a randomized trial of the effectiveness of e-cigarettes as an aid for smokers who were intending to quit. Smokers (N = 657) were assigned to use either nicotine e-cigarettes, nicotine patches, or e-cigarettes without nicotine. Bullen et al. found that although there was no significant difference between the e-cigarettes and nicotine patch groups in verified abstinence at 6 months, time to relapse was significantly longer for e-cigarettes without nicotine. Wagener et al.[6] reported that readiness and confidence to quit increased for a sample of initially unmotivated smokers (N = 20) who were provided with e-cigarettes for *ad libitum* use during 1 week. They also found that ratings of liking and satisfaction for the most preferred e-cigarette (BluCig) were 76% as high as ratings for own-brand cigarette (M = 6.60 and 8.65, respectively). Taken together, these studies provide preliminary evidence that e-cigarettes are effective in terms of reducing symptoms of nicotine withdrawal and may be helpful for smoking cessation.

Another way in which e-cigarettes might help to reduce or eliminate tobacco use would be if smokers viewed them as a cheaper and/or potentially safer alternative or substitute for regular cigarettes. In that case, faced with a price increase for regular cigarettes, for example due to a rising tobacco excise tax,[7,8] smokers might choose to consume more e-cigarettes to compensate for cutting back on tobacco. In this case, consumption of e-cigarettes might increase with the price of regular cigarettes. The slope of the relationship between e-cigarette consumption and regular cigarette price (in logarithmic terms) is known as cross-price elasticity,[9] and provides an index of the substitutability of e-cigarettes for regular cigarettes. For example, if the cross-price elasticity of e-cigarettes for tobacco cigarettes was 0.15, it would indicate that for a 10% increase in the price of tobacco cigarettes the consumption of e-cigarettes would increase by 1.5%.

Cross-price elasticity of nicotine replacement products for cigarettes has been investigated in only a few studies. Using an econometric approach, Tauras and Chaloupka[10] obtained sales data from 50 metropolitan markets in the United States for Nicoderm CQ and Nicorette gum, and estimated their cross-price elasticities as 0.77 and 0.76, respectively. Two studies have used procedures in which smokers make repeated responses (plunger pulls) as a behavioral analogue to price. In this procedure, the number of plunger pulls required for a fixed number of cigarette puffs is manipulated to mimic an increasing price. Shahan, Odum, and Bickel[11] found that as the number of plunger pulls to obtain three cigarette puffs increased from 3 to 12,000, the number of responses to a concurrently-available plunger that produced access to Nicorette gum increased. They estimated the cross-price elasticity of Nicorette to be 0.22. Using a similar procedure, Johnson, Bickel, and Kirshenbaum[12] found that the cross-price elasticities of Nicorette gum and denicotinized cigarettes were 0.19 and 0.20, respectively.

Recently, Huang, Tauras and Chaloupka[13] estimated own-price elasticities of disposable and reusable e-cigarettes as −1.2 and −1.9, respectively, based on data from 52 metropolitan U.S. markets. They also reported positive cross-price elasticities of disposable e-cigarettes as the price of reusable e-cigarettes increased, and vice versa. However, we are aware of no previous studies which have assessed the cross-price elasticity of e-cigarettes and tobacco cigarettes. This is an important question because a positive cross-price elasticity would establish that e-cigarettes are at least partially substitutable for tobacco cigarettes and could be useful for informing policy.

The goal of the present study was to measure cross-price elasticity of e-cigarettes and tobacco cigarettes using a simulated demand procedure in a sample of New Zealand smokers.[14–16] Although e-cigarettes are legal for sale in New Zealand, nicotine-containing liquid for e-cigarettes is only available by import from an overseas country, and we excluded any potential participants who had previously used e-cigarettes (either with or without nicotine). After we assessed demand for tobacco cigarettes using a purchase task based on,[15] participants sampled an e-cigarette containing nicotine and indicated how many e-cigarettes and regular cigarettes they would purchase per day at several prices for regular cigarettes, assuming that e-cigarettes had a fixed price that was cheaper than regular cigarettes.

Method

Participants

The participants were 226 adult smokers recruited by newspaper, community, and internet advertisements from four major New Zealand cities: Auckland (n = 31), Wellington (n = 97), Christchurch (n = 58), and Dunedin (n = 40). Inclusion criteria were that participants needed to be daily smokers, over 18 years old, who purchased their own tobacco and with no intention to quit before 1 January, 2013. Excluded were pregnant/breastfeeding women, current/past users of e-cigarettes, current use of antismoking medication, or use of non-cigarette tobacco. All were interviewed in February–March 2013. The sample was part of a larger study (N = 357) that had previously been recruited and interviewed in November–December 2012,[17] and excluded those who could not be contacted or declined further participation (n = 131). We also excluded those who indicated they had quit smoking by February–March 2013 (n = 16), leaving a final sample size of 210. All received a NZ$15 shopping voucher and a chance to win a tablet computer worth NZ$250 for each interview.

Procedure

All aspects of the study were approved by the University of Canterbury Human Ethics Committee, and participants provided written consent.

Participants first completed a paper-and-pencil demographic questionnaire, which in addition to age, ethnicity, employment, marital status, education, and income, asked how many cigarettes/day they smoked, what type (factory-made (FM) or roll-your-own [RYO]), and the tobacco packets they typically purchased (20, 25, or 30 cigarettes/pack for FM, or 30 g, 40 g, or 50 g for RYO). Next they responded to several addiction questionnaires: The Autonomy Over Smoking Scale (AUTOS),[18] the Fagerstrom Test of Nicotine Dependence (FTND),[19] and the Glover-Nilsson Smoking Behavior Questionnaire (GNSBQ).[20] Participants then completed the Cigarette Purchase Task (CPT). Finally, participants were given the opportunity to sample a nicotinized e-cigarette, rated how much they liked it as well as their own cigarette, and answered questions about their intentions to purchase e-cigarettes and their regular tobacco product.

Addiction Measures

The AUTOS[18] is designed to measure the intensity of three dimensions of nicotine addiction: Withdrawal symptoms, psychological dependence, and cue-induced craving. It includes 12 items scored from 0 to 3 where 0 = "Describes me not at all" and 3 = "Describes me very well." DiFranza et al.[18] showed that the AUTOS had excellent internal consistency reliability and discriminated between smokers who did or did not meet *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* nicotine dependence criteria.

The FTND[19] is a widely-used measure of smoking addiction and includes 6 items scored from 0–3 or 0–1. Items include the number of cigarettes smoked per day and the time until smoking the first cigarette per day. Total scores range from 0 to 10. DiFranza, Morello and Gershenson[21] showed that the FTND and AUTOS had excellent test-retest reliability.

The GNSBQ[20] measures the intensity of behavioral patterns associated with nicotine addiction. It includes 18 items scored from 0 ("not at all") to 4 ("extremely so"); total scores range from 0 to 72. Rath, Sharma and Beck[22] showed that the GNSBQ had good internal consistency and test-retest reliability, and was significantly correlated with nicotine craving.

CPT

The CPT[15] measures demand for tobacco across a range of prices. For use in New Zealand, the CPT was adapted from MacKillop et al. Different versions of the CPT were used depending on whether the participant indicated they smoked FM or RYO tobacco and the size of tobacco packet they typically purchased. All versions had 64 prices displayed in increasing order, similar to previous studies.[15,23]

For the FM smokers, the prices per cigarette ranged from NZ$0 to NZ$5.00. Prices increased by NZ$0.05 for NZ$0 to NZ$2.50/cigarette, by NZ$0.20 from NZ$2.50 to NZ$4.90/cigarette, and by NZ$0.10 to NZ$5.00/cigarette. The price per pack was displayed to the right of each price per cigarette.

For RYO smokers, the prices were listed in terms of cost per 30 g or 50 g tobacco package. To generate prices that were comparable to those used for the FM version of the CPT, prices for the latter were expressed relative to the current market price for cigarettes in November 2012 (NZ$0.70/cigarette), multiplied by the price per package (which was approximately NZ$30.00 and NZ50.00 for 30 g and 50 g packages, respectively), and rounded to the nearest dollar. RYO smokers were asked to assume they would use the same amount of tobacco when rolling cigarettes.

E-Cigarette Sampling and Questions

Participants were then given the opportunity to try an e-cigarette. The experimenter explained how the e-cigarette produced a vapor containing nicotine when inhaled and could be used similar to a regular cigarette. The e-cigarette was the Safe Cigarette brand (no longer available on the U.S. market), was entirely of tobacco extract flavor (excluding tobacco) and labeled as 18 mg/ml for nicotine content. On analysis it yielded 13.95 mg/ml nicotine content, and 200 hand-drawn puffs at 20 mg of nicotine per puff. After taking several puffs on the e-cigarette, participants were asked to rate both their regular cigarette and the e-cigarette for liking and enjoyability on a 10-point scale (1 = don't like at all; 10 = like very much). Participants were then given a sheet which contained three questions about how many e-cigarettes and regular cigarettes they would purchase per day at different prices. The price of the e-cigarette was listed as NZ$0.25 per cigarette which consisted of 15 puffs of vapor. The price of regular cigarettes was listed as either NZ$0.35, NZ$0.70, or NZ$1.40 per cigarette. These prices were chosen so that they would correspond approximately to 0.5×, 1×, and 2× the market price of cigarettes in New Zealand at the time the study was conducted.

Results

Demographic information, smoking habit and addiction scores for the sample are shown in Table 1. The average number of cigarettes smoked per day (cigs/day) was 12.13. Approximately two-thirds (65.7%) smoked FM cigarettes, while one-third (34.3%) smoked RYO tobacco. In terms of ethnicity, 30.2% were Maori or Pacific Island, while 69.8% were New Zealand European or other. The average age was 39.04 years and 59.0% were female.

Simulated demand for tobacco according to the CPT is displayed in Figure 1, which shows the average number of cigarettes per day that participants said they would smoke at prices increasing from NZ$0.00 to NZ$5.00/cigarette. Average responses prior to sampling the e-cigarette are indicated as "baseline" and represent demand for tobacco in the absence of e-cigarette availability as nicotine replacement. For plotting on logarithmic scales, the price for NZ$0.00 was changed to NZ$0.025. Overall demand was a positively decelerating function of price, similar to previous studies with the CPT.[15,16,23]

CPT demand curves were characterized both by measures obtained directly from CPT responses and by an elasticity parameter estimated from fits of[24] exponential model. For direct measures, we calculated the maximum consumption (Q_0) as the demand when cigarettes were free, the maximum amount of money spent per day (O_{max}), and the breakpoint (*BP*) as the first price for which consumption was zero. Hursh and Silberberg's[24] model is:

$$\log_{10} Q = \log_{10} Q_0 + k\,(e^{-\alpha Q_0 C} - 1) \quad (1)$$

where Q is the demand at price C, Q_0 is maximum consumption (i.e., here equal to O_{max}), k is a constant which specifies the range of

Table 1. Demographics, Smoking Habit, and Addiction Scores for the Sample

Gender	
Male	41.0% (*n* = 84)
Female	59.0% (*n* = 121)
Cigarette preference	
Factory-made (FM)	65.7% (*n* = 136)
Roll-your-own (RYO)	34.3% (*n* = 71)
Ethnicity	
European (includes other)	69.8% (*n* = 141)
Maori/Pacific	30.2% (*n* = 61)
Age	
18–24	17.5% (*n* = 34)
25–34	27.8% (*n* = 54)
35–44	17.5% (*n* = 34)
45–54	23.2% (*n* = 45)
55+	13.9% (*n* = 27)
Income	
<NZ$20,000	27.2% (*n* = 55)
NZ$20,000 ≤ x < NZ$30,000	12.4% (*n* = 25)
NZ$30,000 ≤ x < NZ$40,000	11.4% (*n* = 23)
NZ$40,000 ≤ x < NZ$50,000	10.4% (*n* = 21)
NZ$50,000 ≤ x < NZ$60,000	10.9% (*n* = 22)
NZ$60,000 ≤ x < NZ$70,000	8.9% (*n* = 18)
≥NZ$70,000	18.8% (*n* = 38)
Cigarettes/day	12.13 (8.58)
FTND	3.88 (2.18)
AUTOS (total)	17.80 (8.11)
Withdrawal symptoms	5.41 (3.41)
Psychological dependence	5.50 (2.87)
Cue-induced craving	6.92 (2.96)
GNSBQ	15.49 (8.02)

AUTOS = Autonomy Over Smoking Scale[18]; FTND = Fagerstrom Test of Nicotine Dependence[19]; GNSBQ = Glover-Nilsson Smoking Behavior Questionnaire.[20] Means are shown for cigarettes/day and addiction scores (*n* = 210), with standard deviations in parentheses.

possible values in orders of magnitude (here equal to 4, as in previous applications with the CPT[15]), and α is elasticity, a fitted parameter which determines how quickly demand falls with price rises (higher values of α correspond to more rapid decreases with price).

For direct measures, on average participants said they would smoke 17.51 cigarettes/day if they were free (Q_0), would quit smoking when they cost NZ$1.52 each (*BP*), and would spend a maximum of NZ$16.59 per day on tobacco (O_{max}). The fit of Hursh and Silberberg's[24] model (Equation 1) to the average data is also shown in Figure 1. The model fit the data very well, accounting for 89.8% of the variance with α = 0.006. Fits to individual data were more variable, but the model still gave a reasonably good description of the results, accounting for 74% of the variance (mean α = 0.02).

Demand for cigarettes when e-cigarettes were available at NZ$0.25 for 15 puffs are shown by filled triangles in Figure 1 for three prices (NZ$0.35, NZ$0.70, and NZ$1.40/cigarette). To facilitate comparison, these data are shown with baseline demand in the absence of e-cigarette availability in the left panel of Figure 2, separately for FM and RYO smokers. A repeated-measures analysis of variance (ANOVA) with e-cigarette availability and price as within-subjects factors and FM/RYO as a between-groups factor found a significant effect of e-cigarette availability, $F(1,201) = 33.58$, $p < .001$, $\eta_p^2 = .14$, confirming that demand was lower when e-cigarettes were available ($M = 7.03$) than when they were not ($M = 10.95$), a 35.8% reduction. RYO smokers had higher demand overall ($M = 11.00$) than FM smokers ($M = 7.88$), $F(1,201) = 12.28$, $p < .001$, $\eta_p^2 = .06$. The effect of price was significant, $F(2,402) = 201.83$, $p < .001$, $\eta_p^2 = .50$, as were the interactions between price and e-cigarettes, and price, e-cigarettes, and FM/RYO, $F(2,402) = 108.54$, $p < .001$, $\eta_p^2 = .35$ and $F(2,402) = 3.91$, $p < .05$, $\eta_p^2 = .02$, respectively. Post-hoc tests (Tukey honest significant difference) confirmed that the demand for tobacco cigarettes was significantly reduced by e-cigarette availability at prices of NZ$0.35 and NZ$0.70/cigarette, but at NZ$1.40/cigarette, RYO smokers reported more demand for tobacco cigarettes when e-cigarettes were available ($M = 7.88$) than when they were not ($M = 4.78$, $p < .001$) while there was no significant difference for FM smokers (*M*s = 4.18, 4.20; $p = .99$).

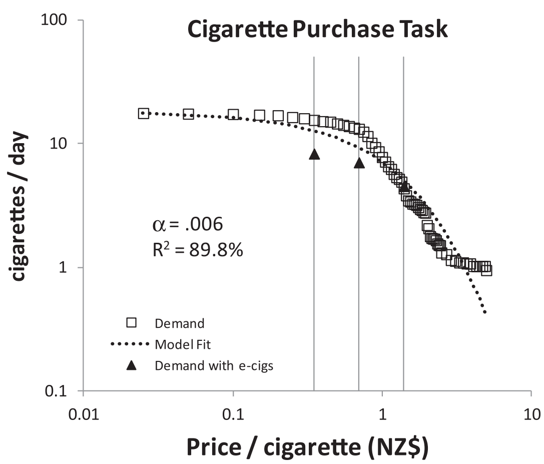

Figure 1. Average demand for cigarettes from the Cigarette Purchase Task (CPT) plotted on logarithmic axes (unfilled squares). The dashed line indicates the fit of Equation 1. The three vertical lines show the prices for regular cigarettes for the simulated demand questions when electronic cigarettes (e-cigarettes) were also available ($0.35, $0.70, and $1.40/cigarette). Demand for tobacco cigarettes when e-cigarettes were available is shown by filled triangles.

To quantify the decrease in demand for tobacco cigarettes with price in Figure 2, we calculated the price elasticity by regressing the (log) cigarettes/day on the (log) price. When e-cigarettes were not available, the elasticities were −0.87 and −0.94 for FM and RYO smokers, respectively. With e-cigarettes, the corresponding elasticities were −0.34 and −0.21.

The right panel of Figure 2 shows simulated demand for e-cigarettes at a constant price of NZ$0.25 per 15 puffs as price of regular cigarettes increased. E-cigarette demand increased with the price of tobacco cigarettes for both FM and RYO smokers, while the latter had higher demand overall. These observations were confirmed by a repeated-measures ANOVA which found significant main effects of both price and FM/RYO, $F(2,406) = 8.72$, $p < .001$, $\eta_p^2 = .05$ and $F(1,203) = 9.63$, $p < .01$, $\eta_p^2 = .04$, respectively, with no interaction ($p = .32$). The linear trend with price was significant for both FM, $F(1,203) = 4.30$, $p < .05$, $\eta_p^2 = .02$, and RYO smokers, $F(1,203) = 7.38$, $p < .01$, $\eta_p^2 = .04$. Averaged across prices, FM and RYO smokers said they would purchase 5.93 and 9.15 e-cigarettes per day, respectively.

Cross-price elasticities were calculated for individual participants as the regression slopes of (log) e-cigarette demand on (log) cigarette price. The average cross-price elasticity was 0.16 (95% CI = 0.09,

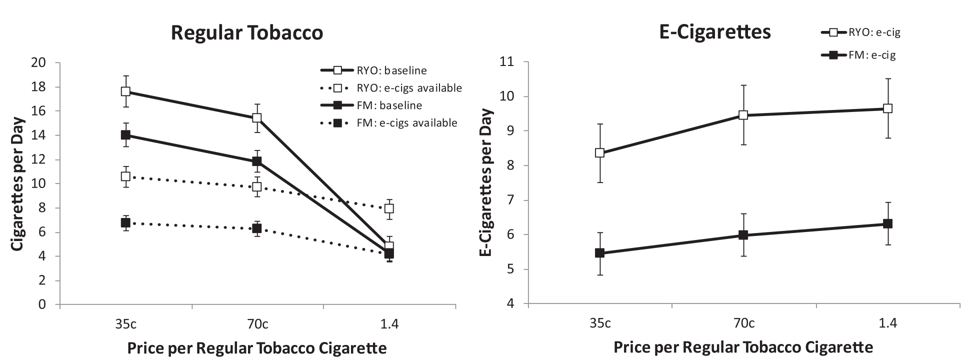

Figure 2. The left panel shows intentions to purchase regular cigarettes per day with electronic cigarettes (e-cigarettes) unavailable ("baseline"; solid lines) and when e-cigarettes were available (dashed lines), separately for factory-made (FM; filled squares) and roll-your-own smokers (RYO; unfilled squares), at prices of $0.35, $0.70, and $1.40/cigarette. The right panel shows intentions to purchase e-cigarettes (at $0.25/cigarette = 15 puffs) when they were available with regular cigarettes separately for FM (filled squares) and RYO smokers (unfilled squares). Bars indicate one standard error.

0.24), which was significantly greater than zero, $t(210) = 4.17$, $p < .001$, $d = .29$. The positive value confirms that e-cigarettes were partially substitutable for tobacco cigarettes. A cross-price elasticity of 0.16 implies that if the price of tobacco cigarettes were to increase by 10%, consumption of e-cigarettes would increase by 1.6%. The cross-price elasticities were not significantly different for FM ($M = 0.18$) and RYO smokers ($M = 0.14$), $t(209) = 0.49$, $p = .63$.

Favorability ratings for participants' own cigarettes were greater than for e-cigarettes for both FM (*M*s = 7.60 and 6.50) and RYO smokers (*M*s = 7.80 and 5.73). A repeated-measures ANOVA confirmed that ratings were significantly higher for own cigarettes than e-cigarettes, $F(1,215) = 10.56$, $p < .01$, $\eta_p^2 = .05$, while the main effect of FM/RYO and the interaction were not significant, *p*s = .57 and .32.

Table 2 shows correlations for the full sample between average demand for e-cigarettes and cross-price elasticity, and other measures including CPT demand indices, own-cigarette and e-cigarette favorability ratings, smoking habit, and addiction scores. Average demand for e-cigarettes was positively correlated with intensity of demand for tobacco, including cigarettes/day ($r = .47$), O_{max} ($r = .44$) and all addiction measures, and negatively correlated with own-cigarette elasticity (α; $r = -.30$). By contrast, e-cigarette cross-price elasticity was weakly (but significantly) correlated with own-cigarette favorability ($r = .14$), but not with any of the other measures. The correlations between e-cigarette demand and cigarettes/day was significantly greater for FM ($r = .54$) than RYO smokers ($r = .24$), $z = 2.41$, $p < .05$, as was that between e-cigarette demand and O_{max}, *r*s = .64 and .12, respectively, $z = 4.29$, $p < .01$. None of the remaining correlations were significantly different for FM and RYO smokers.

Finally we examined whether e-cigarette availability affected participants' stated intentions to quit when cigarette prices doubled from NZ$0.70 to NZ$1.40/cigarette. Intention to quit was defined as reporting zero consumption with price = NZ$1.40/cigarette. When e-cigarettes were not available, responses to the CPT showed that 50.2% (104/207) said they would quit at NZ$1.40/cigarette. However if e-cigarettes were available, only 30.0% (65/217) indicated that they would quit at NZ$1.40/cigarette. The difference in intended quit rates was significant, χ^2 ($df = 1$) = 18.19, $p < .001$. For those who said they would continue to smoke at NZ$1.40/cigarette, demand for cigarettes was lower when e-cigarettes were available ($M = 7.80$) than when they were not ($M = 8.70$), although the difference was not significant, $t(249) = -0.93$, $p = .35$. There were no significant differences in intended quit rates between FM and RYO smokers.

Table 2. Correlations of E-Cigarette Measures (Overall Demand for E-Cigarettes, $M = 7.07$; Cross-Price Elasticity of E-Cigarettes, $M = 0.16$) With Liking/Favorability Ratings, Smoking Habit (Cigarettes/Day), Cigarette Purchase Task (CPT) Derived Measures Based on Fits of Hursh and Silberberg's[24] Model (Equation 1) and Addiction Scores

	E-cigarette demand	Cross-price elasticity
Own-cigarette favorability	−.00 (*n* = 210)	.14* (*n* = 209)
E-cigarette favorability	.28*** (*n* = 207)	−.02 (*n* = 207)
Cigarettes/day	.47*** (*n* = 210)	.06 (*n* = 209)
α	−.30*** (*n* = 205)	−.04 (*n* = 204)
P_{max}	.09 (*n* = 203)	.02 (*n* = 202)
O_{max}	.44*** (*n* = 205)	.04 (*n* = 204)
AUTOS	.29*** (*n* = 206)	.09 (*n* = 205)
GNSBQ	.21** (*n* = 206)	.09 (*n* = 205)
FTND	.36*** (*n* = 206)	.13 (*n* = 205)

AUTOS = Autonomy Over Smoking Scale[18]; FTND = Fagerstrom Test of Nicotine Dependence[19]; GNSBQ = Glover-Nilsson Smoking Behavior Questionnaire[20]; α = elasticity; P_{max} = the price at which the maximum amount of money per day is spent on tobacco; O_{max} = maximum amount of money spent per day on tobacco.

*$p < .05$; **$p < .01$; ***$p < .001$.

Discussion

Our goal was to compare intentions to purchase cigarettes both in the presence and absence of nicotine e-cigarettes as a potential alternative to tobacco, and to test whether demand for e-cigarettes would increase with tobacco price in a sample of New Zealand smokers. We assessed baseline demand for tobacco with a CPT,[15] and then had participants sample an e-cigarette, rate its favorability, and indicate how many e-cigarettes and regular cigarettes they would purchase at various prices. Participants reacted very positively to the e-cigarettes: Favorability ratings were high, and simulated demand for regular cigarettes decreased by an average of 35.8%, and by 42.8% at current market prices when e-cigarettes were available. Assuming that e-cigarettes were less expensive than regular cigarettes (NZ$0.25 per 15 puffs), participants' demand for e-cigarettes increased as the price of regular cigarettes increased from NZ$0.35 to NZ$1.40/cigarette, with an average cross-price elasticity of 0.16. However, results also showed that e-cigarette availability did not decrease intended demand for regular cigarettes at high prices (NZ$1.40/cigarette), and that in fact a significantly lower proportion of participants said they would quit smoking tobacco altogether at NZ$1.40/cigarette if e-cigarettes were available than if not (30.0% vs. 50.2%). Results for FM and RYO smokers were similar, although the latter had higher levels of demand overall for both tobacco and e-cigarettes (Figure 2).

The positive cross-price elasticity indicates that e-cigarettes are at least partially effective as substitutes for regular cigarettes. This was also supported by the reduction in simulated demand for tobacco when e-cigarettes were available, and because e-cigarettes were rated 81.6% as highly as participants' own cigarettes in favorability. These results add to other recent investigations which suggest that e-cigarettes have potential to help reduce tobacco harm. The e-cigarette favorability rating is comparable to,[6] who found that participants rated BluCig e-cigarettes 76.7% as highly as own-brand cigarettes. The cross-price elasticity for e-cigarettes (0.16) was similar to that obtained in behavioral economic studies with nicotine gum and denicotinized cigarettes in which participants made real responses (plunger pulls) for cigarette puffs,[11,12] but lower than for nicotine gum (0.77) in an econometric study across 50 metropolitan areas in the United States.[10] Although reasons for the discrepancy in cross-price elasticity estimates is unclear, it may be associated with use of different methodologies (i.e., individual vs. population-based studies).

However it is important to interpret the results of our study cautiously. We used measures of simulated demand and it is not clear how accurately these will correspond to actual behavior. In particular, the reduction in demand for regular tobacco at current market prices of 42.8% when e-cigarettes were available (Figure 2) is likely very optimistic, given there is little evidence that availability of e-cigarettes as an alternative nicotine delivery system has substantially reduced tobacco demand in countries where they are legal (e.g., United States, United Kingdom). Although the average own-price elasticity for tobacco cigarettes ($M = -0.59$) was in the range reported in previous studies,[25] estimates were lower when e-cigarettes were available ($M = -0.28$) than when they were not ($M = -0.90$), likely due to the large reduction in overall demand with e-cigarettes. Elasticity for tobacco based on the entire demand curve for individual participants (Figure 1; $\alpha = 0.02$) was close to the mean value of 0.03 reported by MacKillop et al.[15]

The most probable reason for the large impact of e-cigarettes is that participants completed the simulated demand task after a brief exposure, and responses may have been affected by a positive first-time impression. Many asked where they could purchase e-cigarettes, and were disappointed to learn that nicotine-containing liquid was not legal for sale in New Zealand. Bullen et al.[5] observed that there is often a short "honeymoon" period in which new users have highly favorable impressions of e-cigarettes, but their enthusiasm often fades with time. However, our estimated cross-price elasticity for e-cigarettes (0.16) appears credible and not over-inflated based on previous behavioral economic studies.[11,12]

An unexpected result was that demand for regular cigarettes at higher prices (NZ$1.40/cigarette) did not decrease when e-cigarettes were available, and the percentage of smokers who said they intended to quit entirely at the higher price was significantly lower when e-cigarettes were available. If corroborated by future studies, this result is potentially problematic, because it suggests that e-cigarettes may be counterproductive in terms of tobacco control when considered in the context of tax policy which increases prices for regular cigarettes relative to e-cigarettes. One possible interpretation of this finding is that smokers may find it easier to maintain a habit in which they smoke occasional regular cigarettes supplemented by less-expensive e-cigarettes, than if they are limited solely to the expensive regular cigarettes. If so, one option for policy makers to consider would be a coordinated tax strategy to ensure that e-cigarettes do not become relatively less expensive than regular cigarettes in the context of tobacco price rises. Excise taxes that increase the cost of tobacco might also increase the cost of e-cigarettes, although e-cigarettes should remain less expensive if they are to be an attractive substitute.

Another notable result was that overall demand for e-cigarettes was positively correlated with smoking habit (cigarettes/day) and level of addiction according to the FTND[19]; AUTOS[18] and the GNSBQ.[20] This is encouraging because it suggests that smokers who are more highly addicted to tobacco are more likely to benefit from e-cigarette availability. Research on the effectiveness of NRT has shown that higher doses of nicotine are more effective in maintaining abstinence with highly-addicted smokers.[26]

The present study had a number of strengths. Only smokers with no prior experience with e-cigarettes were included, so the results accurately reflect the positive impression that our participants had. Although we used a convenience sample, participants were recruited from the community across the country and were generally representative of the smoking population in New Zealand, except that the proportion of females (59%) was larger than for New Zealand smokers in general (47%).[27] Approximately one-third of our sample smoked RYO tobacco, which is consistent with the profile of smokers in New Zealand.[28,29] About one-third was Maori/Pacific Islands ethnicity, compared to 22.3% of the general population, but note that prevalence data indicate that Maori and Pacific Islanders in New Zealand are approximately twice as likely to be a current smoker as those of European origin.

Overall, results of the present study support the view that e-cigarettes may have an effective role to play in a coordinated tobacco control policy. E-cigarettes are attractive to many smokers because they represent a less costly and potentially safer alternative to tobacco cigarettes. Our participants rated e-cigarettes 81.6% as favorably as their own-brand tobacco, and indicated that they would substitute e-cigarettes for regular cigarettes as the price of the latter increased. However, our results also suggest that e-cigarette availability may discourage smokers from quitting entirely as prices of tobacco cigarettes rise. Given that the health effects of long-term e-cigarette use are unknown, the challenge will be to craft policies that take advantage of their potential for harm reduction as substitutes for tobacco, while reducing the prevalence of smoking and nicotine dependence.

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Declaration of Interests

None declared.

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