HHS Public Access

Author manuscript

Drug Alcohol Depend. Author manuscript; available in PMC 2017 December 14.

Published in final edited form as:

Drug Alcohol Depend. 2017 September 01; 178: 551–555. doi:10.1016/j.drugalcdep.2017.06.004.

The Experimental Tobacco Marketplace II: Substitutability and sex effects in dual electronic cigarette and conventional cigarette users

Amanda J. Quisenberry[1], **Mikhail N. Koffarnus**[1], **Leonard H. Epstein**[2], and **Warren K. Bickel**[1]

[1]Virginia Tech Carilion Research Institute Roanoke, VA

[2]University at Buffalo School of Medicine and Biomedical Sciences Buffalo, NY

Abstract

Aim—The aim of the current study was to evaluate tobacco product purchasing in the Experimental Tobacco Marketplace (ETM) among male and female smokers who also use e-cigarettes. We hypothesized a high substitution profile for e-cigarettes and that males would purchase more Snus than females.

Methods—The ETM is an online market used in clinical abuse liability research to mimic real-world purchasing patterns. Tobacco products, including each participant's usual choice of conventional and e-cigarettes, were presented along with a price and description of nicotine content. Participants were endowed with an account balance based on the number of cigarettes and e-cigarettes consumed per week. Each participant was exposed to four ETM sessions in random order during which the price of conventional cigarettes was manipulated.

Results—Cigarette consumption decreased as price increased. A mixed factor three-way ANOVA revealed a significant main effect of price (i.e., more alternative products were purchased at higher cigarette prices), product (i.e., more e-cigarettes were purchased than gum, lozenges, and Snus), and sex (i.e., males purchased more than females). A significant three-way interaction indicated that males purchased more e-cigarettes, Snus, and dip than females at higher cigarette prices.

Conclusion—This study suggests that the user profile of cigarette smokers is associated with behavioral economic measures of alternative product substitution and indicates that the evaluation of nicotine replacement products should be considered for both males and females separately.

Keywords

sex differences; demand; Experimental Tobacco Marketplace; behavioral economics; substitution

Corresponding Author: Warren K. Bickel, Ph.D., The Virginia Tech Carilion Behavioral Health Research Professor, Director, Addiction Recovery Research Center, Virginia Tech Carilion Research Institute, 2 Riverside Circle Roanoke, VA 24016, Professor of Psychology, Virginia Tech, Professor of Health Sciences, Virginia Tech, Professor of Psychiatry, Virginia Tech Carilion School of Medicine, wkbickel@vtc.vt.edu, (540) 526-2088.

1. Introduction

We are in a moment of profound change with the advent of numerous novel tobacco products and a high incidence of morbidity and mortality related to smoking (Jamal et al., 2015; United States Department of Health and Human Services, 2014; World Health Organization, 2011). The behavioral economic assessment of elasticity of demand (i.e., sensitivity to price) and the interaction of commodities as either substitutes, complements, or independents have provided an important framework representing the factors that govern tobacco consumption (Bickel, DeGrandpre, & Higgins, 1995). To explore those factors, we created the Experimental Tobacco Marketplace (ETM), an online store in which the researchers can manipulate price, product availability, and other variables of interest, in an experimental forum resembling the real-world marketplace (Epstein et al., 2012, 2010; Quisenberry et al., 2015).

A fundamental observation of behavioral economics is that the type and number of products in a marketplace can alter demand elasticity and the type and degree of interaction among products (Johnson et al., 2004; Quisenberry et al., 2015). As a result, the ability to achieve the tobacco control goals of reducing product consumption may be informed via the economic processes of substitution and complementarity (Bickel et al., 1995). Substitution defines one end of a continuum representing interactions between two commodities and is described as an increase in the consumption of a fixed-priced product (e.g., Coca-Cola®) while the cost of another commodity (e.g., Pepsi Cola®) is increased. At the other end, commodities function as complements, which refers to the decreased consumption of a fixed-priced product (e.g., soup crackers) in response to an increase in the price of another commodity (e.g., soup). Between these two extremes is independence, which occurs when changes in the price of one commodity (e.g., Coca-Cola®) have little or no effect on consumption of a fixed-priced commodity (e.g., soup crackers). Substitution, complementarity, and independence are measured by cross-price elasticity of demand.

Manipulating price to assess cross-price elasticity of demand using an alternate behavioral economic method of self-administration (Bickel et al., 1995; Johnson et al., 2004) is achieved by increasing the response cost required (i.e., number of plunger pulls). Using this method, Nicorette gum has been shown to function as a substitute (Shahan et al., 2000) when concurrently available with increasing price of cigarettes. An additional study that varied product availability revealed that Nicorette gum and denicotinized cigarettes functioned as a substitutes when each was available independently, but when both were available concurrently denicotinized cigarettes were a greater substitute than Nicorette gum (Johnson et al., 2004).

Product availability has also been shown to influence level of substitution using the ETM methodology (Quisenberry et al., 2015). A two-experiment study where the price of conventional cigarettes was manipulated found differences in the substitution profiles of alternative products when cigarillos were or were not available. In the presence of cigarillos, e-cigarettes and cigarillos were substitutes. However, when cigarillos were removed from the ETM, both e-cigarettes and Camel Snus® functioned as substitutes.

Just as important as the products available are the characteristics of the consumer. For example, e-cigarette substitution of factory made and roll your own cigarettes in New Zealand smokers differed such that consumers of roll your own cigarettes purchased more e-cigarettes than consumers of factory made cigarettes (Grace et al., 2015). With the popularity of e-cigarettes increasing, exploring substitution among different dual users is necessary.

Sex is another important consumer characteristic that influences consumption. Indeed, noticeable sex differences exist in tobacco product use. For example, 9% of females globally smoke cigarettes versus 40% of men (WHO, 2010). Among alternative tobacco products, sex differences exist such that Camel Snus® is more likely to be sampled by males in North America (Biener et al., 2014; Biener and Bogen, 2009) and Sweden (Norberg et al., 2011). In addition, evaluation of the reinforcing efficacy (i.e., the relative ability to maintain or change behavior) of Snus in a self-administration paradigm concluded that Snus administration was associated with decreased latency to smoke cigarettes in males, but not females (Barrett et al., 2011). Similarly, in a naturalistic demand assessment study, males were more likely to purchase Snus than females(Bickel et al., in press; Stein et al., 2016).

The aim of the current study was to evaluate the reinforcing efficacy of conventional cigarettes and alternative tobacco products using the behavioral economic ETM. To this end, male and female dual conventional cigarette and e-cigarette users were exposed to the ETM and purchased products for potentially real use over the next week. We hypothesized that: (1) e-cigarettes would function as a strong substitute at high cigarette prices and (2) males would purchase Snus at a higher rate than females.

2. Materials and Methods

2.1 Participants

Participants were recruited in the Roanoke, VA community via referrals, fliers, and Internet advertisements (i.e., Facebook and Craigslist) seeking electronic cigarette and cigarette smokers for research involving tobacco product purchasing and questionnaire completion. To participate in the study, participants must have met DSM IV (American Psychiatric Association, 2000) criteria for nicotine dependence, reported smoking between 10 and 40 cigarettes per day, smoked an e-cigarette in the last 30 days with the intention to continue, and provided a breath carbon monoxide (CO) level greater than 10 parts per million (ppm; Micro+ Smokerlyzer, coVita/Bedfont, Haddonfield, NJ). Individuals who were planning to move from the area prior to logistically being able to complete the study, individuals who reported unmanaged medical or psychiatric conditions or significant lung or heart conditions, and females who were pregnant or lactating were not eligible to participate. Participants who reported using nicotine products other than cigarettes or electronic cigarettes for more than 10 days out of the last 30 days were also ineligible to participate.

Twenty-two participants completed the study, however one participant’s purchasing session was considered a pilot session. Thus, only 21 participants were included in data analysis. Of those 21 participants, 19% were African American (71% Caucasian and 9% reported other) and 52% were female. Based on the Timeline Follow Back (TLFB) (Sobell and Sobell,

1992), the mean number of cigarettes smoked per day was 18.94 (SD = 7.69) and was not different between females (M = 20, SD = 6.83) and males (M = 17.78, SD = 8.78) [t (19) = .034, p = .855]. The mean number of e-cigarette vaping episodes per day (M = 3.76, SD = 4.56) differed slightly, by sex (Females: M = 4.84, SD = 5.88; Males: M = 2.59, SD = 2.19) [t(19) = 1.14; p = .053]. The Fagerstrom's Test for Nicotine Dependence (Fagerstrom et al., 1996) (FTND) revealed a mean of 6.095 (SD = 2.12) and was not different between males (M = 29.80, SD = 8.89) and females (M = 38.09, SD = 10.19) [t(19) = 1.975, p = 0.063]. Median monthly household income for the sample was $721.00 (range $0 – $5,400; Females: median $1,200; Males: median $721.00) and participants were, on average, 34.14 (SD = 10.27) years old. Age, education, account balance, remaining balance in actualized condition, and number of reported non-study products used at the follow-up session were not different between males and females (p's > .05). In addition, 42.9% of the sample were regular menthol-flavored cigarette users (78% female).

Alternative tobacco product use that did not render the participant ineligible to participate (see eligibility criteria) was minimal in the females sampled. Three females reported any use of alternative products (n = 3), which were all combustible tobacco products. Most males reported use of other products in the 30 days prior to participation (n = 8, 80%), both combustible (n = 3) and non-combustible (n = 3) products; two male participants reported limited use of both combustible and non-combustible alternative tobacco products.

2.2. Procedures

The Virginia Tech Institutional Review Board approved all procedures. Following an initial screening procedure to determine preliminary study eligibility via the telephone, participants visited the laboratory for two assessment visits. During the first visit, informed consent was obtained and smokers were then required to provide a breath CO level of 10 or greater to continue. After confirmation of smoking status, participants completed a set of computerized questionnaires including, the Questionnaire on Smoking Urges Brief (Cox et al., 2001) and the FTND (Fagerstrom et al., 1996). Participants were endowed with an account balance based on their reported consumption via the TLFB of one week's cigarette, electronic cigarette, and other tobacco product use. For example, if a participant smoked 280 cigarettes ($70.00 at market price of $0.25 per cigarette) and used 5 ml of Avail® Stargazer e-liquid per week ($4.00), their account balance would have been $74.00.

With their account balance, participants were asked to purchase nicotine products under 4 price conditions using the ETM (Quisenberry et al., 2015). In the ETM, the participant's usual brand of cigarette (price varied based on condition) and usual brand, type, and dose of electronic cigarette were available (price and mg content varied based on participant's usual choice). The following alternative products were available to participants in the units and at the prices (determined by local average price or in the case of internet purchases for electronic cigarette components, account balance was based on the internet price) indicated: their usual brand of cigarettes (packs, 19.6 mg of nicotine), winterchill flavor Camel Snus® (15-pouch tins, $2.89 each, R.J. Reynolds, Winston-Salem, NC, U.S.A., 27.75 mg of nicotine), classic flavor Skoal dip® (16.8-oz tins, $4.54 each, US Smokeless Tobacco Company, Richmond, VA, U.S.A., 62.4 mg of nicotine), white ice mint flavor Nicorette 4-

mg nicotine gum® (20-count packages, $16 each, McNeil Consumer Healthcare, Fort Washington, PA, U.S.A., 80 mg of nicotine), and mint flavor Nicorette 4-mg nicotine lozenges® (20-count packages, $12 each, McNeil Consumer Healthcare, Fort Washington, PA, U.S.A., 80 mg of nicotine). These products were chosen based on availability at local retail outlets and prior research from our laboratory (Stein et al., 2016) indicating specific brands and flavors were tolerable. Each of four price conditions ($0.12, $0.25, $0.50, and $1.00 per cigarette) were presented in a random order to all participants.

During each price condition, participants were instructed to spend as much time as they needed viewing and exploring the array of product options (images with traditional branding and labeling). Prices for each product were listed beneath the product. When the product image was clicked, an additional page emerged that included a description of nicotine content along with the image displayed in the array. Participants were able to add any number and combination of products to their cart without exceeding their account balance. Following the ETM purchase task, participants chose from a fishbowl one condition to be actualized. The products purchased during the actualized condition were then provided to the participant for use during the next 7-day period. In addition, any remaining account balance after purchases in the actualized condition was provided to the participant. The second session was scheduled for one week later, during which participants reported usage of in- and out-of-study purchased tobacco products.

Data Analysis—To quantify the relationship between purchasing and the price of cigarettes, the data was fit to a modification (Koffarnus and Bickel, 2014) of a model proposed by Hursh and Silberberg (2008):

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

where Q is consumption/purchasing of the commodity (as purchased in the experimental sessions), C is the price, Q_0 is the derived initial consumption without cost constraints (i.e., demand intensity), k is the logarithmic range of the function, and α is the demand elasticity (i.e., sensitivity to price). Q and C are determined by the data and k is a set constant (here 3, which produced the best fit model; R^2 = .5, see Table 1), leaving only Q_0 and α as free parameters to be fit. Throughout the results, the reported Q_0 values are derived using Equation 1.

To determine the relationship between sex, cigarette price, and consumption of the alternative nicotine products available in the ETM, a 2 (sex) × 4 (price) × 5 (product) analysis of variance (ANOVA) was used. Although, a novel cross-price elasticity equation (Hursh and Roma, 2013) can be used to model substitution of alternative products, using 4 price points in the current study limited the fit. An alternate statistical strategy for determining cross-price elasticity is to use a linear regression model and determine the significance of the slope from zero (Quisenberry et al., 2015). Here, at the lowest price point for conventional cigarettes, electronic cigarettes were more frequently purchased, and thus a linear regression model would not be sensitive enough to detect reinforcer interactions. Pmax, the price that evoked the maximum amount spent, and Omax, the amount spent at

Pmax, were calculated with Kaplan & Reed's (Kaplan and Reed, 2014) automated calculator.

3. Results

Account balances (M = 39.21, SD = 17.01) provided to each participant based upon their weekly tobacco use were not statistically different between males (M = 37.20, SD = 20.37) and females (M = 41.04, SD = 14.25) [t (19) = .504, p = .959]. Likewise, the remaining account balance in the actualized condition (M = 12.07, SD = 11.83) was not different between females (M = 13.86, SD = 13.14) and males (M = 10.11, SD = 10.54) [t (19) = .72, p = .336]. Model fit and demand parameters for the total sample, males, and females are presented in Table 1. Comparison of the fitted equations revealed no significant differences between males and females in Q_0 or α [F(2, 79) = 0.52, p = 0.6].

Mauchly's test indicated that the condition of sphericity was violated for both price [$\chi^2(5)$ = 27.17, $p < 0.001$] and product [$\chi^2(9)$ = 79.25, $p < 0.001$], thus degrees of freedom are reported using the Huynh-Feldt correction. The ANOVA revealed significant main effects of product [F(1.99, 37.81 = 6.23, p = 0.005] and price [F(1.80, 34.96) = 10.47, $p < 0.001$]. That is, more products were purchased at the highest cigarette price and more e-cigarettes were purchased than Snus, lozenges, and gum. The between-subjects factor of sex was significant [F(1, 19) = 5.39, p = 0.032], such that males (M = 13.31 mg) purchased more nicotine than females (M = 5.96 mg). A significant sex × product × price interaction was also found [F(4.06, 77.16) = 2.6, p = 0.04]. Relative to other nicotine products, the 95% confidence intervals indicated females purchased more e-cigarettes at the lowest price [95% CI (13.17, 47.19)], while males purchased more Snus at the lowest price [95% CI (0.22, 10.88)]. Males relative to females also purchased more Snus [95% CI at $0.50 (4.08, 23.68); at $1.00 (5.26, 28.04)], e-cigarettes [95% CI at $0.50 (0.43, 43.97); at $1.00 (27.89, 87.11)], and dip [95% CI at $0.50 (6.88, 67.99); at $1.00 (12.49, 87.34)] at the two highest prices.

Figure 1 depicts the consumption of alternative tobacco products across increasing cigarette price by males and females. Own-price elasticity (cigarettes panel) decreased with increasing cigarette price and did not differ by sex. Consumption of alternative products increased at higher cigarette prices, demonstrating their degree of substitutability. On average, males purchased more e-cigarettes, Snus, and dip, than females.

Follow-up data on the reported use of the purchased products and use of products purchased outside of the study show that 12 participants (5 females, 7 males; range 1 – 141 units) used products not provided by the study. These out-of-study products were mostly cigarettes and a few were e-cigarettes. Six participants returned products provided in the study; 2 returned cigarettes, 1, returned cigarettes and e-cigarettes, 1 returned cigarettes and lozenges, 1 returned an e-cigarette and 1 returned an e-cigarette and Snus,

4. Discussion

The current investigation of reinforcer valuation (i.e., the value placed on a reinforcer) using the ETM found that in dual e-cigarette and conventional cigarette users, own-price elasticity of cigarettes decreases as price increases, replicating a common result (Johnson et al., 2004;

Quisenberry et al., 2015; Shahan et al., 2000) in a different population. Evaluation of cross-price elasticity revealed high rates of e-cigarette purchasing across all cigarette prices, with substitution occurring at the highest price condition. E-cigarettes were purchased more than other alternative products and an interaction with sex of the participant revealed that males purchased more e-cigarettes, Snus, and dip than females, especially at high cigarette prices.

Our results suggest that purchasing and substitution profiles are influenced by characteristics of the participant, including sex and patterns of product use. This is important to the behavioral economic study of reinforcer valuation because within a heterogeneous sample, results may be influenced by these characteristics. For example, only males purchased dip in the current study and if the sample were presented as a whole, inaccurate conclusions might be made about the substitution profile of dip due to this unaccounted for source of variability.

The limited substitution profile in females may be related to females having a more difficult time quitting (Cepeda-Benito, Reynoso, & Erath, 2004; Perkins & Scott, 2008; Perkins, 1996), perhaps due to control by the topographical features of smoking and less related to nicotine reinforcement (Perkins, 1996). Indeed, females are less responsive to increases in nicotine dose (Perkins, Jacobs, Sanders, & Caggiula, 2002). One would suspect, then, that alternative forms of nicotine without the same topographical features (e.g., nicotine gum) would not substitute for cigarettes in female smokers. Our results support this claim given females almost exclusively purchased e-cigarettes, which have similar topographical features.

The limitations of this study include collecting data from a small sample in addition to the variation in the type and nicotine content of the e-cigarettes used by participants. To equate the different types of e-cigarettes we evaluated the mg of nicotine purchased and regularly used. Given the numerous types of e-cigarettes (i.e., disposables, tank systems, refillable cartridges), however, substitution should be evaluated in a larger sample between each of these types of products to best determine the characteristics of individuals that result in different substitution profiles to inform tobacco control policies. In addition, unfamiliarity with some options may have affected choice to purchase alternative tobacco products. Future examinations could remedy this limitation by providing a sampling period of all products prior to completion of the ETM session or require no prior use of alternative tobacco products as eligibility criteria. Although this experiment was not designed to address in the substitutability of different flavor options of alternative tobacco products, the flavors presented could have also affected purchasing. Future investigations should determine the flavors of each type of alternative tobacco product that are most and least likely to substitute for cigarettes in different types of users.

In addition, one person returned the two packs of cigarettes purchased in their actualized condition (the highest price condition) because, “they were $40 for the packs” and used all out-of-study products during the week between experimental sessions. This suggests that simply asking participants to comply with the study rules is not sufficient for compliance and may be associated with particular actualized conditions. Only in an actual closed economy situation, can the opportunity for outside consumption be avoided (Koffarnus et al.,

2015). Finally, these data may be biased toward e-cigarette substitution given the recent prior e-cigarette use required for inclusion in the study. For information regarding e-cigarette and other product substitution in a sample of exclusive cigarette users, we direct the reader to Quisenberry et al., 2015, which found consistent e-cigarette substitution in exclusive cigarette smokers. Understanding the substitution profile among all types of tobacco users (e.g., exclusive cigarette, dual users) is important for policy development.

4.1 Conclusions

In conclusion, any intervention focused on altering consumption should consider target characteristics informed by research such as the current article. The ETM provides an experimental forum that resembles real-world purchasing in which to evaluate the interaction among consumption of cigarettes, consumption of alternative tobacco products, and consumer characteristics.

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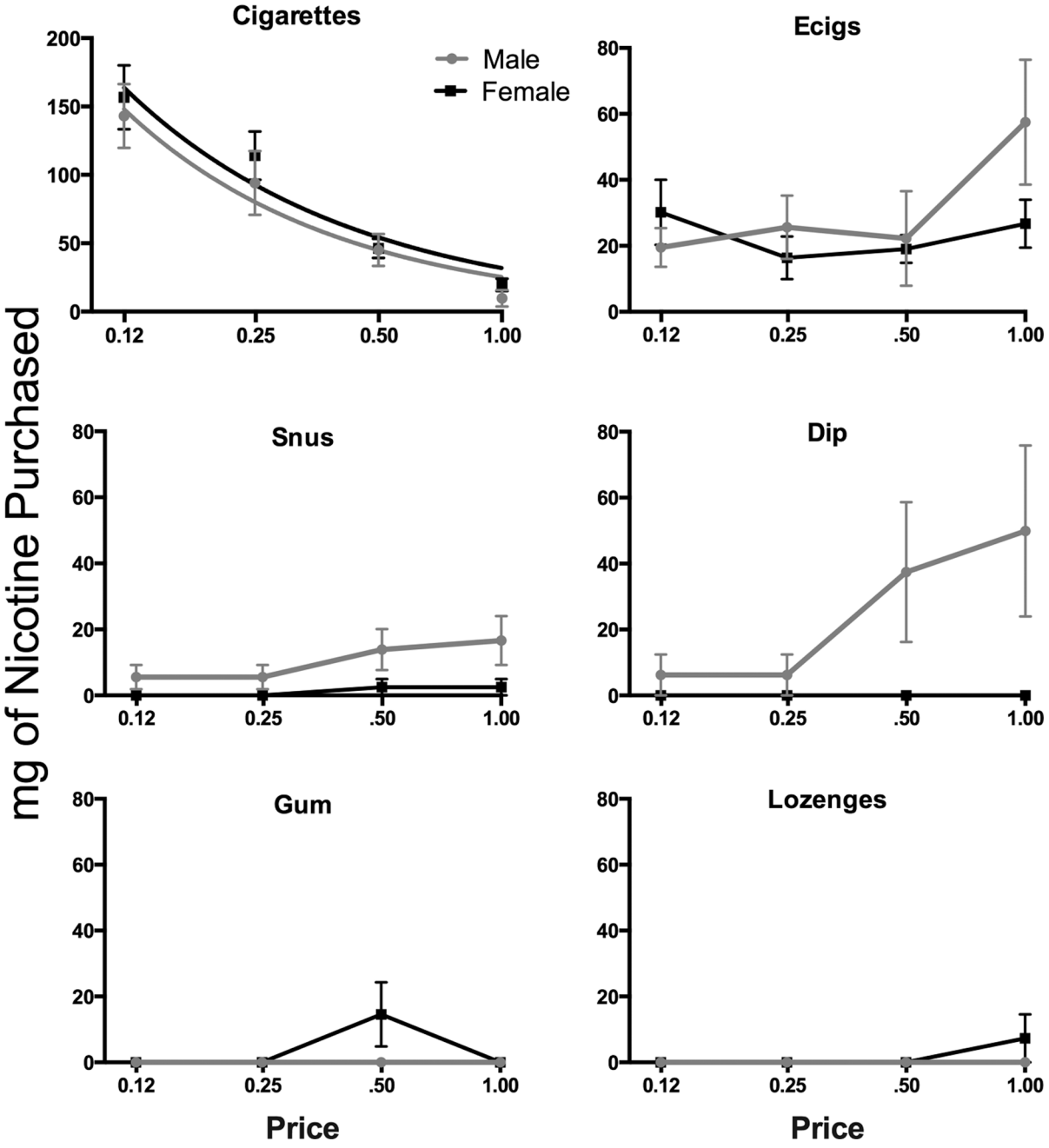

Figure 1.

The upper right panel represents own-price elasticity of cigarettes in male (gray) and female (black) duel conventional and electronic cigarette smokers. The other panels represent cross-price elasticity of each alternative nicotine product in males and females.

Table 1

Model fit and demand parameters for the entire sample, males, and females.

	Total Sample	Males	Females
R^2	0.5	0.47	0.55
Q_0	224.5	213.3	229.6
α	0.0023	0.0014	0.0012
O_{max}	$25.23	$24.26	$28.37
P_{max}	$0.34o	$0.32	$0.35

Q_0=derived consumption at lowest cost, α = demand elasticity, O_{max} = the amount spent at P_{max}, P_{max} = price at which the most money was spent.