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2 The Behavioral Economics of Smoking

Warren K. Bickel and Gregory J. Madden

an adequate science of behavior should supply a satisfactory account of individual behavior which is responsible for the data of economics. . . .
—B. F. Skinner (1953)

The above quote addresses a point central to our discussion; namely, the relation between the behavior of individuals and groups. Traditionally, the behavior of individuals and groups have been the domain of different professions. Individual behavior was the domain of psychology, while group behavior, in terms of the allocation of scarce resources, was the domain of economics. However, some psychologists in the late 1970s began to observe similarities between the phenomena that they studied and economic concepts and principles (e.g., Allison 1979; Green and Rachlin 1975; Hursh 1980; Lea 1978). This precipitated the development of behavioral economics. In the late 1980s, behavioral economics began to be consistently applied to the study of drug abuse and dependence, and today it is an active area of investigation (e.g., Bickel et al. 1990; Bickel et al. 1991; Carroll, Lac, and Nygaard 1989; Hursh 1991).

A critical part of research efforts in the behavioral economics of drug abuse should be to test the limits of the applicability of economic theories and research findings (cf. Sechrest and Bootzin 1996). Understanding these limits will indicate the relation between individual and group drug use and the extent to which one can inform the other. The results of this examination will ultimately influence the relation between the economics and behavioral economics of drug abuse and indicate the extent to which behavioral economic research findings may inform policy.

This examination should attempt to answer two research questions: First,

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are economic concepts and principles applicable to the drug taking of individuals, and second, do behavioral economic data reflect empirical results from econometric studies of drug use? The first of these two questions is a necessary predecessor to the second. If economic concepts and principles are found to be applicable to the drug use of individuals, then the generality of economic concepts is established. Moreover, this generality would permit the study of broad variations in controlling variables in the laboratory. For example, prices in the behavioral economic laboratory can be varied over a greater range than typically observed in the natural economy. Information from such experiments would inform economists about the possible consequences for drug use of larger magnitude price changes.

The second question asks whether the empirical findings noted in the econometrics of drug abuse are observed in the behavioral economics laboratory. For example, if econometric studies find that consumption of a particular drug of abuse differs as a function of gender, then the results from similar conditions across several behavioral economic studies could be examined for those gender differences. Of course, this would require the development of a substantial database from the behavioral economics laboratory, composed of a sample of research subjects that are representative of the populations of interest. Such comparative analyses, to whatever extent possible, would begin to establish the generality and limitations of data collected in the behavioral economic laboratory. Such information would lead to circumscribed and clearly defined justifications for generalizing to policy from behavioral economic laboratory data.

Perhaps the best substance for examining the similarity of the behavioral economics of individual consumption and the economics of aggregate consumption is tobacco smoking. Two reasons support the value of smoking for this comparison. First, tobacco cigarettes are commercially available. Thus, substantial amounts of information about prices and consumption of tobacco cigarettes are available for economic analyses without the difficulty typical with illegal drugs. Second, the behavioral economics of cigarette smoking is among the most developed research areas in the behavioral economics of drug abuse (e.g., Bickel et al. 1990, 1991, 1992), thereby permitting detailed comparisons with econometric studies. Of course, tobacco smoking, as the single greatest preventable cause of death, is an important public health problem to study.

The purpose of this paper is to attempt to answer three questions—two of them posed earlier. First, are economic concepts and principles applicable to the smoking behavior of individuals? Second, do behavioral economic data reflect empirical results from econometric studies of cigarette smoking? Third, can the behavioral economics laboratory evaluate or suggest smoking policies? Before addressing these three issues, we will first describe our experimental paradigm.

2.1 Overview of the Experimental Paradigm and Analysis

Typically, the cigarette smokers that participate in our research are recruited from newspaper advertisements. To participate, each subject must be age 18 or older, smoke 20 or more cigarettes (>.5 mg nicotine yield) per day, and have a carbon monoxide level of greater than 20 ppm. Subjects undergo medical and psychiatric screening prior to participation. Individuals with active alcohol/drug abuse or medical or psychiatric problems that would interfere with participation are excluded. Subjects are instructed not to eat solid foods for 4 hours, not to drink caffeinated or other acidic beverages (e.g., coffee, tea, soda, juice) for 6 hours, and not to drink alcohol for 18 hours prior to the start of the session. Subjects are also instructed not to use illicit drugs for the duration of the study.

The general arrangement that has been employed to examine the behavioral economics of cigarette smoking is as follows. Cigarette smokers come to the laboratory two to five times per week, depending upon the study, to participate in three-hour sessions (see Bickel et al. 1991 for more details). Subjects are required to refrain from smoking for five to six hours prior to each session as indicated by carbon monoxide (CO) breath readings (a reliable indicator of recent smoking). After meeting the CO requirement, the subject is provided with one puff on a cigarette to equate time from last cigarette smoking across subjects. The session begins 30 minutes later.

In most of our experiments, we do not employ a medium of exchange (e.g., money). Thus, subjects must make a specified number of responses in order to smoke. A response is defined as a complete pull and reset of a brass plunger (Gerbrands no. G6310) located on a console in front of the subject. At the beginning of each session, the subject is informed of the number of responses required for access to a cigarette and the number of puffs on that cigarette that will be permitted upon each completion of the response requirement. In most cases, completion of a response requirement results in the administration of two to four puffs on a cigarette. During the sessions, the subject sits alone in a small room with the response apparatus, a radio, and the local newspaper. When the response requirement is completed, the subject is provided with the specified number of puffs on a cigarette. Puffs are inhaled using a controlled puffing procedure (Griffiths, Henningfield, and Bigelow 1982; Zacny et al. 1987). Specifically, subjects inhale through a puff-volume sensor that provides visual and auditory feedback designed to ensure that subjects inhale 70 cc (+/− 5 cc) per puff throughout the experiment. Various modifications of these basic procedures will be discussed below as they become relevant. Note that unless otherwise specified, consumption refers to the number of puffs on a cigarette that are smoked and drug-seeking refers to the number of responses on the plunger.

2.2 Are Economic Concepts Relevant to the Cigarette Smoking of Individuals?

Fundamental to economics is the concept of demand and the demand law. First, *demand* is the quantity of a good or reinforcer that an individual will purchase or consume at the prevailing price (Pearce 1989; Samuelson and Nordhaus 1985). Second, the *law of demand* specifies that the amount of a good that will be bought will decrease with increases in price, all other things being equal (Pearce 1989). If the demand law is applicable to cigarette smokers, then consumption should decrease as price increases.

The law of demand is illustrated by a recent study conducted in our laboratory (Bickel et al. 1995). Five cigarette-deprived smokers could obtain two puffs on a cigarette for completing 100 responses. In a later session, the requirement was increased to 400 responses, a fourfold increase in price. Figure 2.1 illustrates that this increase in price decreased each subject's consumption in accordance with the demand law. Note that the results are not peculiar to

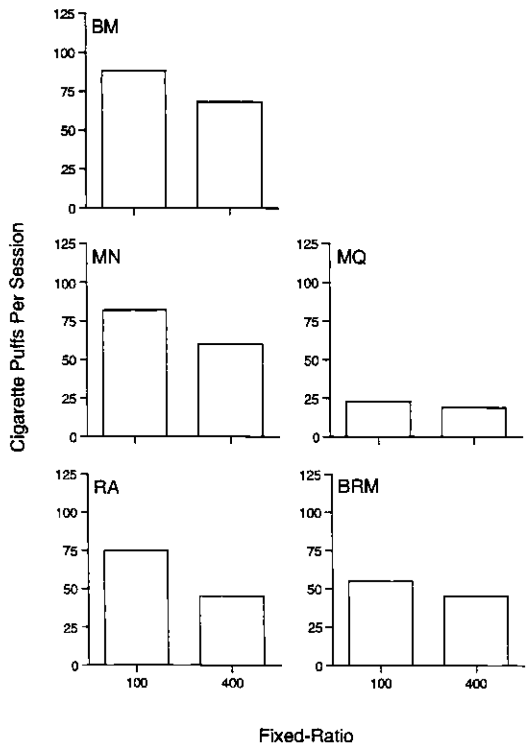

Fig. 2.1 Number of cigarette puffs individual subjects smoked in each three-hour session at two different response requirements
Source: Bickel et al. (1995).

Table 2.1 Individual Participants' Price Elasticities Reflecting the Change from FR 100 to FR 400

Participant	Elasticity
BM	−0.21
MN	−0.22
MQ	−0.16
RA	−0.41
BRM	−0.17

Source: Bickel et al. (1995).
Note: FR = fixed-ratio.

these subjects nor to this preparation. Indeed, the effects of increasing price via response requirements has been demonstrated with a wide variety of drug and other reinforcers in several species (Griffiths, Bigelow, and Henningfield 1980).

One way to quantify the effects of price is with a measure of demand referred to as price elasticity. Table 2.1 displays price elasticity coefficients for the data presented in figure 2.1. The across-subject mean elasticity is −.23, with elasticity coefficients ranging from −.16 to −.41. These coefficients indicate that demand is inelastic and relatively insensitive to price. Econometric assessments of cigarette price elasticity of demand typically range from −.16 to −.80 (Andrews and Franke 1991). Although the price elasticities of our laboratory smokers fell within this range of elasticities estimated by econometricians, it should be noted that the latter elasticity estimates take into consideration price effects on both cigarette consumption and the decision to smoke (i.e., initiation of smoking in nonsmokers). Because the latter is not assessed in our laboratory studies, our elasticity estimates over the price range shown in figure 2.1 would probably be higher than econometric estimates of price elasticities based on cigarette consumption alone.

Although a single price elasticity value is provided by examining the effects of a single price increase, elasticity may not be constant across a broad range of prices. Examining a broad range of prices is a strength of laboratory behavioral economic research. As mentioned earlier, the price range that can be imposed in a laboratory setting can far exceed the range of prices observed in the natural economy of cigarette smokers. For example, in some of our studies prices can range from 1 to 2,600 or more, which spans more than three orders of magnitude. By assessing a variety of prices, demand can be displayed graphically as a demand curve, where the amount of goods consumed is plotted as a function of that good's price (Pearce 1989).

Figure 2.2 displays demand curves from the same five subjects whose data were presented in figure 2.1 (note the double-logarithmic axes). The demand curves illustrate the relation between cigarette consumption and the unit price at which cigarette puffs could be purchased. Unit price is defined as a cost-benefit ratio: the number of responses made in order to obtain each cigarette

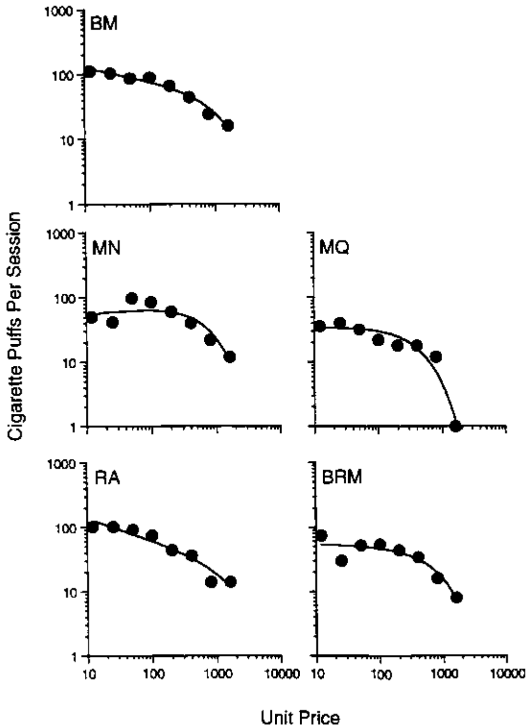

Fig. 2.2 Number of cigarette puffs individual subjects smoked in each three-hour session at a range of unit prices

Source: Bickel et al. (1995).

Note: Note the double-logarithmic axes. Demand curves were fit to consumption data using eq. (2).

puff. The data in figure 2.2 are plotted according to mathematical convention, where the independent variable is plotted on the horizontal axis and the quantity consumed is plotted on the vertical axis. Thus, these axes are inverted relative to economic convention. The line of best fit is derived by an equation developed by Hursh et al. (1989) to model consumption (see eq. [1]). Consumption generally decreases as price increases, consistent with the law of demand. Importantly, these data indicate that elasticity (slope of the demand curve when plotted on logarithmic axes) changes throughout the demand curve, with the absolute value of elasticity increasing as price increases.

Given that elasticity is changing continuously as price changes, point elasticities were calculated for each price. Point elasticity is the slope of the line tangent to a point on the demand curve (see eq. [3]). These coefficients (displayed in table 2.2) show that the absolute value of elasticity tends to increase as price increases. At low prices, elasticity values are near zero and positive in value in a few cases. As price increases, elasticity becomes more negative until at the higher prices they are elastic (i.e., >1 in absolute value). A commodity

Table 2.2 **Individual Participants' Price Elasticity Values at Eight Different Unit Prices**

		Unit Price							
Participant	Average	12	25	50	100	200	400	800	1,600
BM	−0.49	−0.21	−0.22	−0.24	−0.27	−0.34	−0.49	−0.78	−1.35
MN	−0.45	0.10	0.08	0.04	−0.03	−0.17	−0.45	−1.02	−2.16
MQ	−0.83	0.01	−0.02	−0.07	−0.18	−0.40	−0.83	−1.70	−3.44
RA	−0.52	−0.34	−0.35	−0.36	−0.38	−0.43	−0.52	−0.71	−1.09
BRM	−0.49	−0.04	−0.05	−0.08	−0.14	−0.26	−0.49	−0.96	−1.89

Source: Bickel et al. (1995).

that is inelastic at the lower range of prices and becomes more elastic at higher prices is considered to exhibit mixed elasticity (Hursh and Bauman 1987). Moreover, consumption can be said to positively decelerate as a function of price increases when plotted in log coordinates. Mean point-price elasticities for each subject are displayed in table 2.2. The across-subject mean elasticity was −.56, with mean elasticity coefficients ranging from −.45 to −.83. These data suggest that elasticity is nonlinear and that the shape of the demand function may prove useful in making predictions about the effects of price changes on cigarette demand. We will address this later in greater detail.

Of course, these results may be peculiar to environments without a medium of exchange. To address this, DeGrandpre and Bickel (1995) conducted a study where a medium of exchange was employed. Subjects were presented with the opportunity to earn money by completing a response requirement. The money earned could then be spent on cigarettes. To obtain the opportunity to smoke also required that subjects complete a response requirement in order to spend their money on cigarette puffs. In this way, the cost of cigarettes was broadened to include both monetary cost and the effort (e.g., travel time to the store) required to obtain cigarettes. In each session, subjects made a number of response requirements to obtain 25 cents and completed a range of response requirements to spend their earnings on cigarettes. Money could not be taken home and was relevant only in the context of the session.

Figure 2.3 shows the demand curves obtained when puffs purchased per session are plotted as a function of the unit price of cigarette puffs (here the response and monetary cost of cigarettes are included in calculations of unit price). The demand curves shown in this figure are generally similar in shape to those seen in figure 2.2; that is, consumption is a positively decelerated function of price increases. Also, note the between-subject differences in the sensitivity of consumption to price. The latter differences are evident when point elasticities at each unit price are examined (table 2.3). As price increases, demand for cigarettes becomes progressively more elastic. The across-subject mean elasticity was −1.58 and mean elasticities ranged from −.66 to −3.27. Note that the elasticities are higher than in the preceding study; however, so is

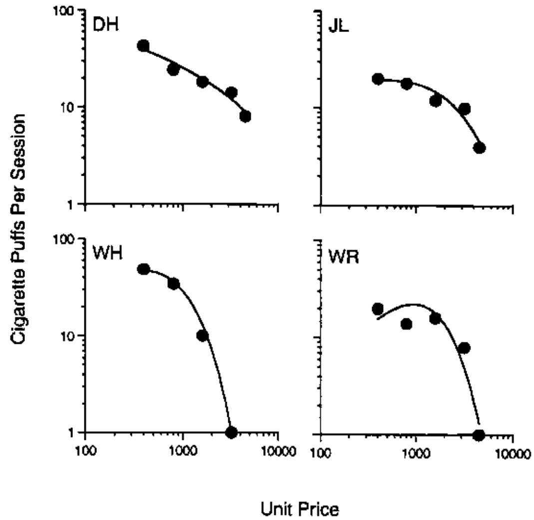

Fig. 2.3 Number of cigarette puffs individual subjects smoked in each three-hour session at a range of unit prices

Source: DeGrandpre and Bickel (1995).

Note: Note the double-logarithmic axes. Demand curves were fit to consumption data using eq. (2).

Table 2.3 Individual Participants' Price Elasticity Values at Five Different Unit Prices

		Unit Price				
Participant	Average	400	800	1,600	3,200	4,500
DH	−0.66	−0.44	−0.49	−0.60	−0.81	−0.99
JL	−0.80	−0.03	−0.16	0.56	−1.34	−1.98
WH	−3.27	−0.05	−0.81	−2.32	−5.35	−7.81
WR	−1.57	0.73	−0.19	−0.89	−3.06	−4.82

Source: De Grandpre and Bickel (1995).

the range of prices examined. In this study, prices ranged from 400 to 4,500, while in the prior study prices ranged from 12 to 1,600. Given that elasticity is price dependent as shown in both of these data sets, these differences in elasticity are to be expected when different prices are examined.

Although the demand curves examined thus far are somewhat variable across subjects, they may all be described as positively decelerating when plotted on log coordinates, and all show mixed elasticity. Thus, the important characteristics of laboratory smokers' demand curves are observed whether or not a medium of exchange is employed in manipulations of price.

One important question about these data is the generality of the findings: Are these findings restricted to the laboratory where sessions are three hours long and puffs are delivered instead of cigarettes or packs? The usefulness of behavioral economic data would be enhanced to the extent that these results are related to broader aspects of economic behavior. To address this, we will first consider whether similar results would be obtained if longer duration studies were conducted.

In 1966, Jack Findley reported a study that he conducted where a cigarette smoker lived 24 hours a day in an experimental space. In order to obtain cigarettes, the subject had to complete a response requirement. The response requirement was varied across days, not within. Thus, Findley employed procedures nearly identical to those used in our experiments, but he expanded the duration of the session to 24 hours and used whole cigarettes instead of puffs on a cigarette.

Data from Findley's (1966) experiment are presented in figure 2.4. When plotted in double log coordinates, cigarette smoking decreased as a positively decelerating function of cigarette price. As the response requirement increased (25, 50, 100, 200, 300, and 500), elasticity increased from values near zero, indicating inelastic demand, to elastic demand at the highest price (see table 2.4). Overall mean elasticity was −.41. Thus, these data indicate that demand

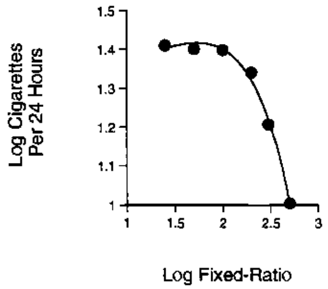

Fig. 2.4 Number of cigarette puffs smoked per 24-hour period across a range of response requirements

Note: Consumption data were estimated from Findley's (1966) figure 7. The demand curve was fit using eq. (2). Data on both axes were converted to logarithms to show proportional change in consumption as a function of price increases (i.e., the point slope of the demand curve provides a measure of elasticity).

Table 2.4 A Single Smoker's Price Elasticity of Demand for Cigarettes While Continuously Housed under Laboratory Conditions

Unit Price	Point-Price Elasticity
25	0.08
50	0.01
100	−0.14
200	−0.43
300	−0.72
500	−1.30
Average	−0.41

Source: Findley (1966).

curves observed in our laboratory sessions appear representative of consumption across full days and when whole cigarettes are purchased. However, Findley's data were also collected under laboratory conditions.

To further assess the generality of the shape of demand curves observed in our laboratory, in figure 2.5 we reanalyzed the aggregate U.S. cigarette consumption data that were reported by Lewit (1989). In that paper, Lewit reported annual average price of cigarettes in the United States as a function of calendar years (Lewit's fig. 2) and per capita cigarette consumption (Lewit's fig. 5). From these data we produced a demand curve by plotting annual per capita consumption of cigarettes as a function of the average cigarette price in that calendar year (note the double-logarithmic coordinates). Although other data provided in Lewit's figures were adjusted for inflation, it is unclear from Lewit's figure 2 whether average annual cigarette prices were adjusted for inflation. Our figure 2.5 illustrates that although cigarette prices did not span a large range, the shape of the demand curve is similar to those obtained in our laboratory setting. Point elasticities are provided in table 2.5 at each of the prices shown in the figure. Again, elasticity increases across this price range, and overall elasticity for these data is −.29.

The shape of the cigarette demand curve may have substantial generality across other drugs as well. For example, consider the data presented in figure 2.6. In the figure, demand curves were reanalyzed from several drug self-administration studies that employed a variety of drugs and species, including monkeys and rats (Bickel et al. 1990). Regardless of whether cocaine, PCP, or pentobarbital was being self-administered, the shape of the demand curve generally conformed to that characterizing demand for cigarettes.

Together, the data examined thus far suggest that basic principles and concepts of economics apply to the behavioral economics laboratory where the behaviors of cigarette smokers are studied. The data demonstrate that elasticity changes continuously throughout the demand curve and that mixed elasticity

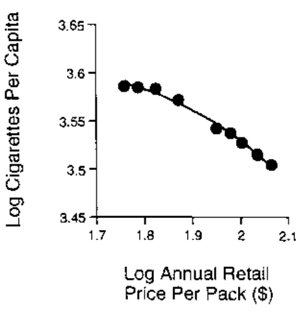

Fig. 2.5 Per capita cigarette consumption as a function of the annual mean price per pack of cigarettes

Note: Price and consumption data were estimated from Lewit's (1989) figures 2 and 5, respectively. The demand curve was fit to these data using eq. (2). Data on both axes were converted to logarithms to show elasticity changes as a function of price.

Table 2.5 **Point-Price Elasticities and Average Price Elasticity Derived from U.S. Smoking, 1979–87**

Price (Cents per Pack)	Point-Price Elasticity
57	−0.14
61	−0.16
67	−0.19
74	−0.23
89	−0.32
95	−0.38
101	−0.38
108	−0.43
116	−0.47
Average	−0.29

Source: Lewit (1989).

is often observed. The shape of this function is observed when both response requirements are manipulated and when medium-of-exchange procedures are employed. Moreover, the shape of the demand function appears to have generality to 24-hour sessions, when full cigarettes are earned, to aggregate U.S. consumption, and to other drugs of dependence when studied in laboratory settings. Together, these data answer in the affirmative our question regarding the relevance of basic economic concepts to the cigarette smoking of individuals.

2.3 Does Behavioral Economic Data Reflect Empirical Results from Econometric Studies of Cigarette Smoking?

To assess whether cigarette smoking in the behavioral economics laboratory may serve as an adequate model of smoking in broader economic contexts, we sought to compare data collected in our laboratory over the past eight years with some major findings in the smoking literature. First, we compared price elasticity of demand for cigarettes in the behavioral economics laboratory with those commonly reported by econometricians and those derived from per capita U.S. smoking. Next, we assessed whether demographic characteristics known to correlate with price elasticity values and rates of cigarette consumption could also significantly account for the observed variance in elasticity and consumption of cigarettes in our laboratory. To the extent that laboratory and nonlaboratory demand for cigarettes are comparably affected by smokers' demographic characteristics, behavioral economic data may be useful in predicting the effects of cigarette price increases outside the range investigated in econometric studies.

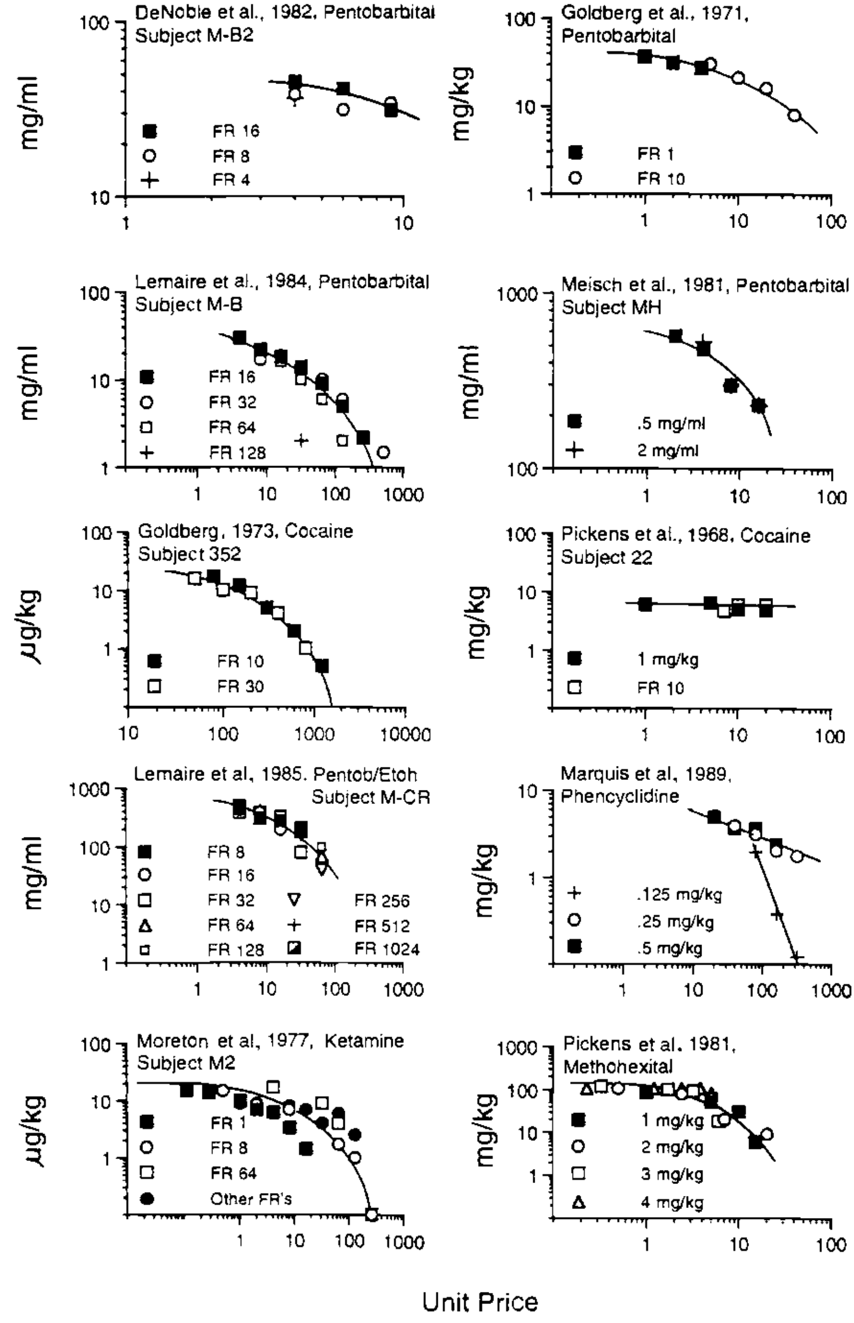

Fig. 2.6 Amount of drug consumed per drug self-administration session across a range of unit prices

Source: Bickel et al. (1990).

Note: Note the double-logarithmic axes. The unit price of six different drugs or drug combinations was manipulated either by changing the dose of drug delivered at each self-administration or by changing the response requirement necessary to produce one self-administration.

2.3.1 Price Elasticity

Cigarette-smoking data were collected from subjects who participated in 1 of 17 different experiments. Because each of these experiments was designed to investigate a different aspect of demand for cigarettes, we used only those subjects whose data had been collected under conditions most commonly employed in our studies. That is, data were included in the analysis if cigarette-deprived subjects pulled a response plunger at different response requirements to self-administer cigarette puffs in three-hour sessions. We included in the analysis only those subjects' data that included at least four different unit prices. A minimum of four unit prices is required to fit the demand curve (see eq. [1] below). Because we were interested in the relation between demographic characteristics of individual smokers and their cigarette intake, we included only one demand curve for each individual subject. For subjects who had completed multiple experiments, data from the experiment corresponding to the highest R^2 was used. These inclusion and exclusion criteria yielded 74 separate demand curves, each derived from individual-subject data.

The functional relation between cigarette-puff consumption (C) and unit price (P) was modeled by using the following equation (Hursh et al. 1989):

$$C = Lp^{b}e^{-ap}, \tag{1}$$

or, restated in logarithmic coordinates,

$$\ln C = \ln L + b(\ln P) - aP, \tag{2}$$

where L and b are related to initial consumption and slope of the demand curve, respectively, and a is a measure of acceleration in slope. Parameter estimates were obtained through linear regression techniques. Demand curves fit through individual-subject data accounted for a mean of 92 percent of the variance (SD = 9.4 percent).

Table 2.6 shows demographic characteristics of the final group of subjects employed in the present analyses. Subjects were about evenly split between males and females, were primarily white, and were, on average, middle-aged, high-school educated, and unemployed. Subjects tended to smoke more than a pack of cigarettes and drink about three cups of coffee per day. Most subjects drank alcohol, with about one-third of all subjects reporting regular drinking (i.e., two or more drinking episodes per week) and over half of the subjects reporting consuming more than one drink at each episode. Fagerström Tolerance Questionnaire (FTQ) scores suggested our average subject was nicotine dependent, while the average Beck's Depression Inventory score was in the non-depressed range.

Although our sample of subjects well represented the range of some demographic characteristics (e.g., gender), others were constrained relative to the demographics of U.S. smokers. For example, our subjects smoked an average

Table 2.6 **Demographic Characteristics of 74 Smokers Whose Data Were Included in the Present Analysis**

Characteristic	Mean (SD)	Percent of Subjects
Male		56.7
Age	32.0 (8.6)	
Cigarettes per day	25.7 (7.9)	
Fagerström Tolerance Questionnaire score	7.5 (1.4)	
Caucasian		94.0
Education (years)	12.7 (2.1)	
Employed (full or part time)		44.6
Coffee per day (cups)	2.9 (2.9)	
Alcohol consumption		
Nondrinkers		25.7
1–2 times/month		27.0
1 time/week		16.2
2–3 times/week		24.3
4+ times/week		6.8
Consuming <2 drinks per episode		50.1
Beck's Depression Inventory score	4.0 (4.2)	

of 26 cigarettes a day with a one standard deviation range of 18 to 34 cigarettes. During the period 1990–91 (the most recent period for which demographic data were available), the average U.S. smoker consumed approximately 19 cigarettes per day and approximately 35 percent of all smokers consumed fewer than 15 cigarettes per day (Giovino et al. 1994). Younger smokers and heavy alcohol users are not represented in our sample because persons under the age of 18 and those suspected of having a drinking problem were excluded from participating in the experiments. Unemployed or underemployed smokers tend to be overrepresented in our sample given that most subjects participated during business hours for modest compensation. Further, the ethnic mix of the U.S. population was not well represented in our sample of smokers, although it was representative of the geographic location in which the experiments were conducted.

Figure 2.7 shows the predicted number of cigarette puffs consumed per session as a function of eight different unit prices (10, 25, 50, 100, 200, 400, 800, 1,600); note the double-logarithmic coordinates. The eight unit prices shown were selected because they correspond to the range typically examined in our laboratory studies and are approximately equidistant when plotted on logarithmic coordinates. Because subjects were generally not given the opportunity to earn cigarette puffs at each of these unit prices, the number of puffs consumed per session at each unit price is estimated from average parameter values of individual subjects' demand curves. As figure 2.7 illustrates, logarithmic demand for cigarettes was a positively decelerating function of logarithmic price increases.

Price elasticity of demand values were calculated at each of the eight differ-

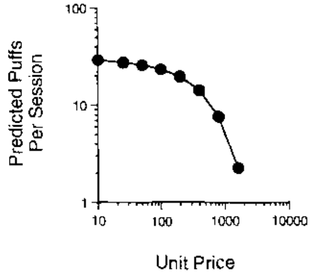

Fig. 2.7 Mean predicted consumption across a range of unit prices typically examined in the behavioral economics laboratory

Note: See text for details on estimating individual subjects' predicted consumption at each unit price. The demand curve was fit to these predicted consumption values using eq. (2).

Table 2.7 Mean of Individual Subjects' Estimated Price Elasticity of Demand Values at Eight Different Unit Prices

Unit Price	Price Elasticity of Demand	Standard Error
10	−0.072	0.028
25	−0.098	0.027
50	−0.141	0.027
100	−0.228	0.036
200	−0.400	0.065
400	−0.746	0.134
800	−1.436	0.277
1,600	−2.816	0.564
Mean	−0.742	

ent unit prices from parameters of individual subjects' demand curves using the following equation:

$$E = b - aP. \tag{3}$$

The mean and standard error of these estimated values are shown in table 2.7. As defined by the model of cigarette consumption employed (eq. [1]), price elasticity values are a decreasing linear function of price.

Clearly, the range of price elasticity of demand values presented in table 2.7 is wider than is typically reported in econometric studies investigating the effects of price fluctuations on demand for cigarettes (e.g., Andrews and Franke 1991; Townsend 1987). In the latter, average price elasticity values typically range between −0.4 (Lewit and Coate 1982) and −0.8 (Andrews and Franke 1991). Only a portion of our empirically derived demand curve (between unit prices 200 and 400) possessed elasticities approximating the range reported by econometricians. At unit prices lower than 200, demand was more inelastic, and at prices higher than 400, demand shifted from inelastic to elastic.

Thus, mean price elasticities derived from individual smokers' laboratory demand curves are in part consistent with values reported in econometric studies of cigarette demand. These data may suggest that cigarette smokers in Vermont (the state in which our experiments were conducted) are more sensitive to cigarette price fluctuations than are the aggregate U.S. smokers represented in major econometric studies. Alternatively, the price elasticity differences that were observed (below and above unit prices 200 and 400, respectively) may be a function of the limited range of cigarette prices typically examined in econometric investigations of cigarette smoking—limited, that is, when compared with the 160-fold range of unit prices represented in table 2.7. As shown in table 2.5, price elasticity values of U.S. demand for cigarettes range between −0.14 and −0.47 when prices are varied across an approximately two-fold range. While this range is still constrained relative to the mean elasticities reported in table 2.7, the shape of the U.S. demand curve shown in figure 2.5 suggests that further price increases would produce greater shifts toward elastic demand.

In summary, mean elasticities generated in the behavioral economics laboratory are partially consistent with elasticities reported in econometric studies of cigarette smoking. Differences are hypothesized to be the result of the broader range of unit prices examined in our lab than cigarette prices in econometric investigations. Our laboratory demand curve closely resembles U.S. demand for cigarettes when prices are varied across a twofold range.

2.3.2 Demographics of Smoking

The demographics of our sample of smokers (table 2.6) provide the opportunity to examine if the number of cigarette puffs consumed per session and price elasticities of demand across a range of unit prices are affected by characteristics of the smokers participating in our laboratory studies. If some of these characteristics are found to explain the variability in smoking rates and sensitivity to price within the lab, then these relations between demographics and smoking can be compared with demographic effects observed outside the lab. That is, characteristics of real-world smokers that are known to affect per capita cigarette consumption or price elasticity of demand could be compared with those demographics found to affect smoking in our laboratory. Consistent demographic effects across laboratory and nonlaboratory settings would further support the use of the present methods as a model of population-level cigarette smoking and, in addition, would suggest that laboratory results obtained from subjects with specific demographic characteristics can be used to predict the effects of price changes on the behavior of demographic subpopulations of cigarette smokers.

Two cautions are warranted, however, before we endeavor to make these comparisons. First, as noted above, some demographic subpopulations of smokers were not well represented in our sample. For some demographics, ethical or practical constraints barred us from gathering a more representative sample of smokers. For example, teenage and alcoholic smokers were excluded from participating in our experiments. Although no systematic income data were collected from our sample of smokers, we believe that smokers in higher socioeconomic (SES) classes were not well represented because most experimental sessions were conducted during business hours and subjects were required to participate for several weeks in each experiment. Also, we suspect that the monetary compensation employed was insufficient to attract higher SES smokers. Second, our sample of smokers is far smaller than those employed in econometric studies. Thus, a failure to observe consistent demographic effects between behavioral economic and econometric studies indicates either that our sample was unrepresentative of the population of smokers, that our sample size was insufficient to detect significant differences, or that behavioral economic laboratory data cannot be used to predict effects of cigarette price changes on demand of demographic subpopulations of smokers.

Numerous studies, some of them econometric, have outlined the demographics of cigarette smoking. For example, male smokers typically smoke more cigarettes per day than female smokers (Giovino et al. 1994), and male demand for cigarettes tends to be more price elastic than is female demand (Chaloupka 1990; Chaloupka and Wechsler 1991; Mullahy 1985; although see Townsend, Roderick, and Cooper 1994). Age is positively related to the number of cigarettes consumed per day (Giovino et al. 1994), and some econometric studies have found a negative relation between age and price elasticity (e.g., Lewit and Coate 1982), although the latter effect appears primarily due to a decrease in the number of young people who begin smoking after cigarette price increases (Lewit and Coate 1982; Lewit, Coate, and Grossman 1981). Additionally, unemployed and lower SES persons are more likely to be smokers (Hay and Foster 1984), although most econometric studies have reported greater price elasticity in lower socioeconomic status smokers than in wealthier populations of smokers (Atkinson, Gomulka, and Stern 1984; Fry and Pashardes 1988; Townsend 1987; Townsend et al. 1994).

Other demographic variables represented in our sample of laboratory smokers are known to be correlated with smoking rates, topography, or success in attempts to quit smoking, but their relation to price elasticity, to our knowledge, has not been investigated. The Fagerström Tolerance Questionnaire (FTQ) is an eight-item paper and pencil measure of nicotine dependence (Fagerström and Schneider 1989). Higher FTQ scores are correlated with less success in attempts to quit smoking (Pinto et al. 1987). Education level is both negatively correlated with U.S. per capita smoking rates (Pierce et al. 1989) and the number of cigarettes consumed per day (Giovino et al. 1994). Alcohol consumption has also been found to modestly but significantly correlate with daily cigarette intake (Craig and Van Natta 1977).

To compare demographic effects between our sample of laboratory smokers and smokers outside the lab, we began by confining our comparison to the unit-price range possessing price elasticities comparable to mean elasticities reported in econometric studies. Thus, our initial comparison was confined to unit prices 200 and 400 (mean arc elasticity = −0.44; SE = 0.40). The demographic characteristics listed in table 2.6 were considered as potential predictors in stepwise regression analyses for (i) arc elasticity across unit prices 200 and 400, (ii) cigarette intake per session at unit price 200, and (iii) intake at unit price 400. Demographic variables were chosen for inclusion in the model if the F-to-enter was significant at $p \leq .10$.

Arc Elasticity

Table 2.8 shows the two demographic variables that were significant in predicting arc elasticity across unit prices 200 and 400: FTQ score and years of education. Panel *A* of figure 2.8 shows the relation between FTQ scores and predicted arc elasticities, while panel *B* illustrates the relation between education level and predicted arc elasticities. FTQ scores of 4, 7, and 10 served as low, middle, and high values, respectively, and 9, 12.5, and 16 years of education were used to represent the range of education levels (each of these values fell within the range observed in our sample of smokers). At high FTQ scores, demand for cigarettes was more inelastic than at low scores, consistent with FTQ as a measure of nicotine dependence. Similarly, cigarette demand is more inelastic in less-educated smokers than in highly educated smokers. Thus, the most inelastic demand in this unit-price range is predicted for poorly educated smokers with high FTQ scores.

To our knowledge, neither FTQ score nor education level has been studied in econometric studies of price elasticity of demand for cigarettes. FTQ scores are predictive of success in smoking cessation treatment studies (e.g., Pinto et al. 1987) and may, therefore, be predictive of price elasticity of demand for cigarettes (although the latter has not been empirically determined). Consistent with this argument, smokers with higher FTQ scores tend to compensate more efficiently when changed to low-nicotine-yield cigarettes (Fagerström and Bates 1981), a change that may be conceptualized as a price increase (i.e., lower nicotine delivery for the same amount of money spent on cigarettes; see

Table 2.8 Demographic Variables That Were Significant in Stepwise Regression Analysis Predicting Arc Elasticity across Unit Prices 200 and 400 (prediction made for elasticities of log consumption)

Order	Parameter Coefficient	R^2
Constant	−0.43 (0.40)	
FTQ score*	0.08 (0.02)	0.05
Education level*	−0.05 (0.03)	0.05
Overall		0.10

Note: Parameter coefficients (SE) of each variable in the final equation are shown with percent variance accounted for by individual variables and the full model.

$^*p \leq .10$

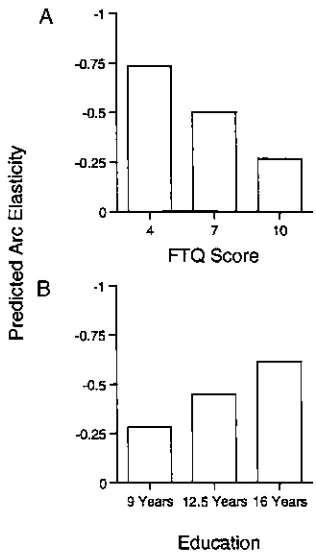

Fig. 2.8 Predicted arc elasticity values as a function of *A*, Fagerström Tolerance Questionnaire (FTQ) score and *B*, years of education

Note: This figure illustrates predicted arc elasticity values across a change in unit price from 200 to 400 as a function of three different levels of the two demographic characteristics of our subjects that significantly predicted arc elasticity changes in a stepwise regression analysis: Fagerström Tolerance Questionnaire (FTQ) scores and years of completed formalized education.

DeGrandpre et al. 1992) that induces compensatory behavior representative of inelastic demand. Further, high FTQ scores would appear to predict inelastic demand for cigarettes in nicotine-dependent smokers, who are more likely to experience withdrawal symptoms relative to nondependent smokers, when nicotine intake is decreased in the face of cigarette price increases. The latter, however, is not empirically supported, as Hughes and Hatsukami (1986) found no significant relation between FTQ score and nicotine withdrawal severity. Thus, the relation between FTQ score and price elasticity requires prospective empirical study to determine if the present finding accurately characterizes the behavior of smokers outside the laboratory.

The relation between education level and price elasticity of demand shown in figure 2.8 is qualitatively consistent with the observation that smoking prevalence rates have declined more in smokers with a high-school education or higher (Escobedo and Peddicord 1996), although the latter findings may be more a function of public education efforts concerning the health risks of smoking than they are indicative of price elasticity differences across education levels. Indeed, Chaloupka (1991) reported that education was negatively related to price elasticity of demand, a result opposite that obtained in our sample of laboratory smokers. The inconsistency between our findings and those reported by Chaloupka may be due to our sample of smokers inadequately representing the larger population of cigarette smokers. In particular, the range of SES levels of U.S. smokers does not appear to have been well represented in our sample of laboratory smokers, and SES is a variable known to correlate with education level (e.g., Neisser et al. 1996). Although SES data were not systematically collected in our sample, we believe lower SES smokers were disproportionately represented. Most of our subjects (55.4 percent) were unemployed, and 45 percent of our employed subjects were employed part time only. Further, subjects in our experiments agreed to participate in exchange for $35 (U.S.) per day, a rate likely to attract predominantly lower SES smokers. Thus, in our relatively homogeneous group of lower SES subjects, education was positively related to price elasticity. Whether the same education-consumption relation would be observed in low SES smokers in the natural economy remains an empirical question.

Noticeably absent from the variables significantly predicting variance in elasticity between unit prices 200 and 400 were gender and age, both of which have been reported to affect price elasticity of demand for cigarettes (e.g., Townsend et al. 1994). *T*-tests of elasticity at unit prices 200 and 400 (calculated from eq. [3]) revealed no significant effect of gender at either unit price. Because male and female smokers were about equally represented in our sample, the failure of this demographic to account for variability in elasticity in our smokers is surprising. The insignificant effect of age on price elasticity, however, may be due to the lack of younger smokers in our sample. Townsend et al. (1994) found no systematic effect of age on elasticity above age 24. In our sample of smokers, 77 percent were 25 years or older. Thus, age may have failed to significantly account for variance in elasticity simply because of our lack of sufficient variability in smokers' ages.

Cigarette Consumption at Unit Prices 200 and 400

Five demographic variables significantly accounted for variance in the number of cigarettes puffs consumed per session at unit price 200, and four of these variables were significant at unit price 400. Table 2.9 shows the order in which variables were selected in stepwise regression, parameter coefficients, and percent variance accounted for by each variable in the final equations. In figure 2.9, predicted smoking rates at unit prices 200 and 400 are shown as a function of gender (panel *A*), education level (panel *B*), FTQ score (panel *C*), alcohol consumption per episode (panel *D*), and employment status (panel *E*). In each panel, cigarette consumption was estimated by multiplying each significant demographic variable's parameter coefficient by a high and low value of the demographic at unit prices 200 and 400. High and low parameter values fell within the range of observed values of each demographic variable. The mean of the remaining demographics in the regression equations were multiplied by their parameter coefficients.

Several findings corresponded with demographic trends observed in U.S. smokers. First, consistent with data reported by Giovino et al. (1994), male

Table 2.9 Demographic Variables That Were Significant in Stepwise Regression Analysis Predicting Cigarette Puff Intake per Session at Unit Prices 200 and 400 (prediction made for log consumption)

Unit Price	Order	Parameter Coefficient	R^2
200	Constant	3.31 (0.56)	
	FTQ score*	0.15 (0.05)	0.09
	Education level*	−0.10 (0.03)	0.11
	Gender (male = 1)**	0.39 (0.14)	0.05
	Alcohol per episode**	−0.35 (0.14)	0.06
	Employment status***	−0.24 (0.14)	0.03
	Overall		0.34
400	Constant	3.13 (0.73)	
	FTQ score*	0.19 (0.06)	0.11
	Education level*	−0.14 (0.04)	0.12
	Alcohol per episode***	−0.38 (0.19)	0.03
	Gender (male = 1)***	−0.35 (0.18)	0.04
	Overall		0.29

Note: Parameter coefficients (SE) of each variable in the final equation are shown with percent variance accounted for by individual variables and the full model.

$^*p \leq .01$

$^{**}p \leq .05$

$^{***}p \leq .10$

laboratory smokers consumed more cigarette puffs per session than females. Thus, although laboratory elasticities were nonsignificantly affected by gender across the unit price 200 to 400 range, cigarette consumption was sensitive to this variable. Second, consistent with data summarized by Pierce et al. (1989), education was negatively related to cigarette intake. Thus, our highly educated subjects smoked fewer cigarette puffs per session and showed greater price elasticity of demand. Third, higher rates of intake were predicted by the stepwise equation for subjects with high FTQ scores, an unsurprising result given that self-reported daily smoking intake is an item on the FTQ. Panel *D* of figure 2.9 illustrates an unanticipated finding: Subjects who reported drinking fewer than two alcoholic beverages per drinking episode were predicted to smoke more cigarette puffs per session than heavier drinkers. Finally, unemployed subjects were predicted to be heavier smokers than employed subjects at unit price 200; employment did not account for significant variance in consumption at unit price 400 (and thus is not shown in figure 2.9).

In summary, education level and FTQ score accounted for significant variance in arc elasticity across the unit price 200 to 400 range. To our knowledge, these demographic variables have not been studied as predictive of price elasticity of demand in econometric studies of cigarette smoking. Age and gender, two variables found to affect population-level price elasticities, did not significantly account for variance in arc elasticity across this range of unit prices.

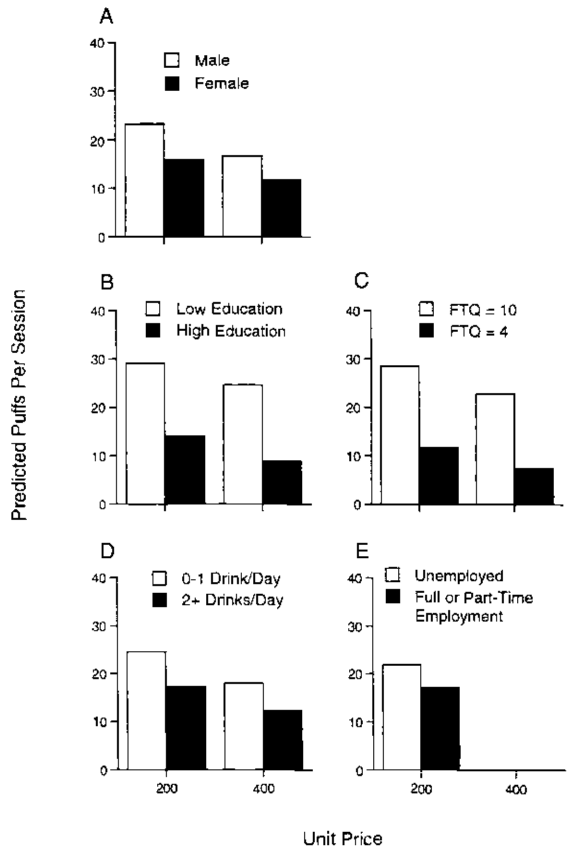

Fig. 2.9 Predicted number of cigarette puffs consumed per three-hour session at unit prices 200 and 400

Note: Individual graphs show effects on smoking of demographics that significantly predicted consumption in stepwise regression (*A*, gender; *B*, education; *C*, FTQ score; *D*, alcohol consumption per episode; *E*, employment status). Effects of employment status on predicted consumption are not shown at unit price 400 because this demographic was not significant at this unit price.

Whether these inconsistencies are representative of a quantitative difference between laboratory and nonlaboratory demand when cigarette prices are manipulated, or are due to a lack of variability in the demographics of our sample of laboratory smokers (age) or statistical power (age and gender) remains unclear. Regardless of their origin, these inconsistencies fail to support using the results of the present experiments as predictors of specific age and gender subpopulations of smokers' reactions to cigarette price changes.

With the exception of alcohol use per drinking episode, smokers' demographic characteristics affected the amount smoked at unit prices 200 and 400 in a direction consistent with demographic effects observed at the population level of smokers. These consistencies suggest that the present data set could be used to predict whether demographic effects observed within this confined range of unit prices (viewed as representative of cigarette prices outside the lab) would be maintained if cigarette prices are increased or decreased to levels outside this range. Because the effects of alcohol consumption variables on smoking rates did not correspond with reported correlations between alcohol use and cigarette consumption rates outside the lab, these variables were not subjected to further analysis.

Demographic Effects on Cigarette Consumption across a 160-Fold Range of Unit Prices

T-tests were used to compare the predicted number of cigarette puffs consumed per session at each of eight different unit prices across two levels of the demographics shown in table 2.6. Thus, continuous demographic variables (e.g., age) were dichotomized at a level that resulted in two approximately equally sized samples. The same eight unit prices used to estimate demand in figure 2.7 were employed for this analysis. Cigarette consumption per session was again estimated from mean demand curve parameters using equation (1).

Panel *A* of figure 2.10 shows the effects of gender on predicted cigarette consumption across this range of unit prices. At unit prices up to 200, males were predicted to smoke significantly more puffs per session than were female smokers. However, as unit prices increased above 200, gender differences failed to reach significant levels. These data may suggest that if cigarette prices were increased above current levels, male and female smokers would tend to smoke about the same number of cigarettes per day. These data also suggest an elasticity difference between male and female smokers across the lower range of unit prices; however, this difference was not detected in our stepwise regression analysis of arc elasticity across unit prices 200 and 400. The suggested trend toward greater price elasticity in male smokers is consistent with some (e.g., Chaloupka 1990; Chaloupka and Wechsler 1991; Mullahy 1985) and inconsistent with other (Townsend et al. 1994) econometric findings.

Panel *B* of figure 2.10 shows a similar effect profile of age on cigarette intake across the eight unit prices. For purposes of these analyses, smokers over and under age 30 were treated as separate groups. Older smokers smoked significantly more cigarette puffs per session than younger smokers at unit prices less than 200. At higher unit prices, intake differences observed across the different age groups failed to achieve significance, suggesting again that if cigarette prices were increased, demographic differences in smoking rates would wane.

Panel *C* of figure 2.10 illustrates that significant cigarette intake differences were observed at all eight unit prices across two levels of education. Education was dichotomized into two groups of subjects (less than and at least a high-school education). Predicted consumption levels were significantly higher for subjects with less than a high-school education. Panel *D* of figure 2.10 shows

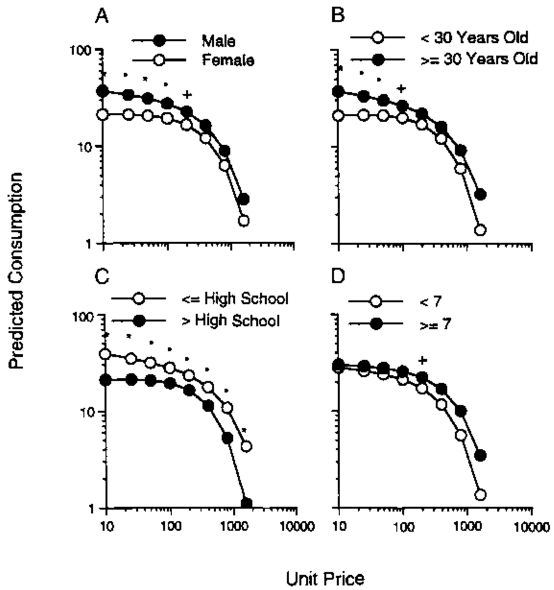

Fig. 2.10 Demographic effects on predicted number of cigarette puffs consumed per three-hour session at the range of unit prices examined in fig. 2.7
Note: A, gender; *B*, age; *C*, education; *D*, FTQ score. *T*-tests revealed significant consumption differences (*: $p \leq .05$; +: $p \leq .10$) across the two levels of each demographic at some unit prices.

that FTQ scores were significant or approached significance only at unit prices higher than 200.

2.3.3 Summary and Conclusions

So, does the behavioral economic data reflect empirical results of econometric studies of cigarette smoking? Using behavioral economic laboratory smoking data to predict population-level changes in price elasticity of demand was supported by two pieces of evidence. First, the range of price elasticities commonly reported in econometric studies fell within the range of elasticities derived from demand across the 160-fold range of unit prices examined. Second, price elasticities indicative of more extremely inelastic demand than is typically reported in econometric studies were consistent with price elasticities derived from U.S. per capita smoking rates across a twofold range of cigarette prices. Laboratory data indicative of extreme elasticity were hypothesized to be a function of the higher prices employed in our studies than have been implemented in the U.S. tobacco market.

Our retrospective stepwise regression analysis of demographic variables accounting for variance in price elasticity, however, revealed significant effects of FTQ score and education level when elasticities were examined in a unit-price range considered representative of prices typically examined in econometric studies. Gender and age, two variables found to affect price elasticity in econometric studies of cigarette smoking, did not significantly account for elasticity variance in our sample of laboratory smokers. Thus, little evidence was gathered to support using behavioral economic laboratory smoking data to predict how price changes might affect price elasticity in specific demographic subpopulations of smokers. However, the possibility that the latter conclusion represents a type II error should not be overlooked given the small samples size employed (relative to econometric studies) and the fact that our sample of smokers was not representative of many of the demographic characteristics of cigarette smokers.

Finally, demographic characteristics known to affect the number of cigarettes consumed per day were, in general, predictive of cigarette smoking rates in the behavioral economics lab. Thus, across the lower range of unit prices examined, men tended to smoke more per session than women, and participants over age 30 smoked significantly more than their younger counterparts. In the upper range of unit prices, these demographic differences disappeared as smoking rates converged around minimal consumption levels. More highly educated subjects smoked significantly less per session throughout the unit-price range.

The notable exception to the consistencies between demographic variables affecting laboratory and nonlaboratory smoking rates was alcohol use, which is positively related to daily smoking rates in smokers outside the lab but was negatively related to puffs per session in the lab at nearly all but the highest unit price. There are at least two possible explanations for this discrepancy. First, heavy drinkers were excluded from participating in our studies. Perhaps if this population of smokers been included, laboratory smoking would have been positively related to alcohol consumption. Second, there is evidence to suggest that cigarettes and alcohol are complementary goods (e.g., Zacny 1990). In a complementary relation, increasing the availability of one good (e.g., soup) increases the consumption of that good and its complement (soup crackers). If a complementary relation exists between cigarettes and alcohol, then our heavier drinkers may have been lighter smokers in thc lab because alcohol was unavailable during the sessions and negative blood alcohol level readings were required for participation.

2.4 Can the Behavioral Economics Laboratory Be Used to Develop and Evaluate Economic Policy Recommendations for Cigarette Smoking?

The preceding section suggests that when we aggregate our data, we obtain results that are generally consistent with smoking in the natural economy. When disaggregated into demographic subgroups, our data are in some cases consistent with the economics of smoking in the natural economy and in some cases not. This suggests that while our laboratory model may not accurately predict the reactivity of certain subgroups of smokers to cigarette price changes, our model nonetheless seems to conform to aggregate smoking in the natural economy. As such, the relation between laboratory studies and aggregate smoking may permit us to explore experimentally the consequences of policies already imposed and to examine other economic phenomena that may inform smoking policy, although the results of these experiments may not reflect how certain subgroups may respond. To this end, we will summarize the results of an experiment with policy-making implications (DeGrandpre et al. 1993). This experiment provides an empirical demonstration of the economic concepts of normal and inferior goods, and here we will discuss the implications of these findings for smoking policy.

Normal and inferior goods are concepts that may have important implications for the relative pricing of nicotine replacement products and tobacco cigarettes. Normal goods are defined as commodities that are increasingly consumed as income increases. In contrast, consumption of inferior goods decreases when income increases. For example, at low incomes, more hamburger (inferior good) is consumed than steak (normal good). As income increases, consumption of hamburger decreases as consumption of steak increases.

In the experiment conducted by DeGrandpre et al. (1993), smokers who had abstained from smoking for five to six hours before each session were allowed to choose between two cigarettes: (1) their usual brand, or (2) another brand that the subjects previously rated as being least preferred on a menu of cigarettes with equivalent nicotine content. Subjects could purchase either their usual brand at the price of 50 cents per two puffs or the less-preferred brand for 10 cents per two puffs. These prices remained constant throughout the experiment. Income (the amount of money they were given at the beginning of each session) was varied across sessions, and unspent money was forfeited at the end of the session.

Figure 2.11 shows that as income increased, consumption of the preferred brand of cigarettes (filled squares) increased and consumption of the nonpreferred brand (open squares) decreased in all seven subjects. Increased consumption of the usual brand and decreased consumption of the less-preferred brand of cigarettes as incomes were increased empirically demonstrate normal and inferior goods, respectively. Further, these data demonstrate that income changes can produce preference reversals even when reinforcer type, magnitude, and price remain unchanged. Such a demonstration suggests that income can be a powerful variable influencing drug choice.

These data suggest that two forms of differentially priced nicotine may be used in lieu of one another depending upon income. This result has some interesting implications for nicotine-replacement products that deliver nicotine but do not produce the negative health outcomes associated with inhaling the smoke of burnt plant product. These nicotine-replacement products provide only a small part of the package associated with tobacco smoke (e.g., nicotine)

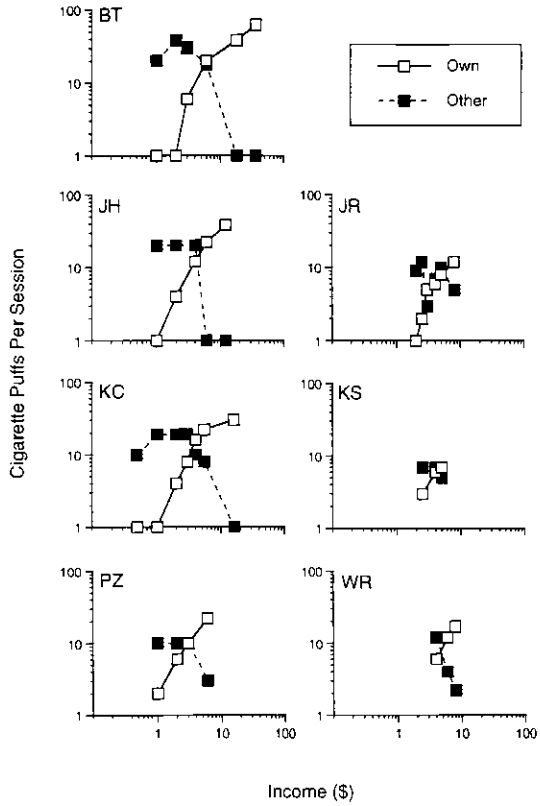

Fig. 2.11 Effects of income manipulations on the number of subjects' own brand and a less-preferred brand of cigarettes consumed per three-hour session
Source: DeGrandpre et al. (1993).

and do not provide others (e.g., taste). Thus, these products may substitute for one another, but the nicotine-replacement products may function as inferior goods relative to tobacco smoking. As such, health policies to produce harm reduction could consider two coordinated policies. First, the safer nicotine-replacement products could be widely available (e.g., in convenience stores) with prices lower than tobacco cigarettes. Second, tobacco taxes could be raised substantially so that smokers, to continue smoking at the same rate, would experience a reduction in real income. As such, lower-income individuals in particular would be expected to switch to the inferior but safer product. Given that lower SES groups have been relatively insensitive to prior public policy and educational efforts designed to reduce cigarette smoking, data from the present experiment suggest a novel approach in reaching a particularly at-risk segment of cigarette smokers. These speculations may be worth exploring in future behavioral economic studies.

2.5 Overall Conclusions

In this paper, we attempted to answer three questions relevant in considering the relationship between the economics and behavioral economics of smoking. We answered in the affirmative the question concerning the applicability of economic principles and concepts to the smoking behavior of individuals. Our data suggest that economic principles and concepts are relevant and do pertain to individual smokers. Moreover, the demand curves obtained in these experiments appear to have wide generality.

To the question, Does the behavioral economic data reflect the empirical results in econometric studies of cigarette smoking? our answer is not a simple yes or no. The analysis of demand reveals several points of comparability when our sample is compared to overall U.S. consumption. However, when our sample is broken into subgroups, the data are consistent with the economic literature for some demographic analyses but not for others. Whether the inconsistencies are due to restricted sample size, an unrepresentative sample, or some other reason is not yet clear. Nonetheless, these results suggest that the use of the behavioral economic data to model the behavior of particular subgroups of cigarette consumers is very limited at this time.

To the third question, regarding the use of the behavioral economic laboratory to examine issues of policy, the answer is a qualified yes. These studies can inform policy makers because our laboratory model demonstrates economic principles and examines the potential consequences of using a range of cigarette prices beyond what is typical in the natural economy, and our results tend to be consistent with overall U.S. demand. However, given our answer to the second question that we posed, the applicability of these results to any demographic subgroup must be made cautiously. Nonetheless, the type of experiments reviewed here may be useful in modeling the outcomes of health policy and therefore could inform policy makers.

In closing, the behavioral economics of smoking is an evolving field. The current evaluation shows that the economics and the behavioral economics of smoking share a great deal. They may usefully inform each other because economic principles are germane for understanding the smoking behavior of individuals and groups. Together, they may better describe the effects of variables that importantly affect cigarette smoking and point to new directions for improving public health.

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Comment on Chapters 1 and 2

Kenneth E. Warner

Introduction

Comparison of behavioral economic laboratory studies and econometric analyses of large data sets drawn from real-world behavior is particularly desirable and feasible in the case of cigarette smoking. It is desirable because there are many policy issues that can be informed by research. It is feasible because there are excellent data on consumption and price for the econometrics studies, and a good standardized product commercially available for the laboratory experiments. As a consequence, there is a relatively rich literature on both sides of this disciplinary divide.

These two papers ably demonstrate both the potential and limitations of their respective discipline-based approaches to understanding the determinants of demand for tobacco products. More importantly, each paper ventures off the beaten path to examine some questions of considerable significance that have largely eluded attention until now.

Tobacco Taxes, Smoking Restrictions, and Tobacco Use

The paper by Ohsfeldt, Boyle, and Capilouto is noteworthy for the authors' attempt to delve into the determinants of the demand for smokeless tobacco products, and the substitutability of snuff for cigarettes and vice versa. For years, it has been widely believed that other tobacco products are not good substitutes for cigarettes. Recently, however, Rodu (1995) has proposed that physicians prescribe smokeless tobacco for their smoking patients as a substitute for cigarettes. Although this is a very controversial proposal (Tomar 1996), it is predicated on Rodu's belief that smokeless tobacco—a less harmful, although not harmless, method of ingesting nicotine—is indeed a satisfactory substitute for cigarettes for many smokers. In this paper, the authors produce

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evidence that cigarette price increases *do* lead to substitution toward snuff, lending support to Rodu's belief.

The tobacco price elasticity literature is focused almost exclusively on cigarettes. Therefore, this contribution, and the authors' related work more generally (Ohsfeldt and Boyle 1994), is most welcome. Nevertheless, ultimately the study is plagued by serious data problems that limit its utility in assessing the determinants of the demand for snuff and the substitutability of snuff for cigarettes. The authors note many of these problems themselves. Two of the most important are the following: (i) the CPS data permit analysis only of the effects of taxes and smoking restriction policies on the *prevalence* of tobacco use and not its intensity; and (ii) there are no price data available for snuff products. Therefore, the authors assume that price variation is a function only of tax variation. Tax is almost certainly the largest source of price variation, but a recent analysis of cigarette price data has concluded that manufacturers do engage in limited price discrimination by state (Keeler et al. 1996). As such, this assumption is at the very least imperfect.

As they note, the authors derive some odd findings. We cannot dismiss the possibility that these are artifacts of data problems. Most notably, the cross-tax elasticity of 1.0, when a cigarette tax is treated as endogenous, seems improbably large. Also, the effect of smoking restrictions *increases* when regulation is treated as endogenous, contrary to what both theory and past empirical evidence suggest (Chaloupka and Saffer 1992).

The data problems in the study by Ohsfeldt and colleagues nicely illustrate a limitation of much of the econometric analysis in the substance abuse literature (and elsewhere, for that matter); it is, perhaps, one of the more important lessons emerging from this conference in general. Economists typically rely for their econometric analyses on existing data sets created by other people, often not economists, who frequently have different purposes in mind while designing the data sets. As such, the data sets are rarely completely appropriate to the task of providing the "perfect" data for the purposes of the study in question. This often leads to the kinds of limitations and problems encountered in the Ohsfeldt paper. This is hardly a fatal flaw. Typically, economic analyses effectively exploit existing data sets to derive important insights about the question at issue. Nevertheless, recognition of this limitation serves to remind us to be cautious in how, and how strongly, we interpret our findings.

The Behavioral Economics of Smoking

The paper by Bickel and Madden presents a nice overview of the behavioral economics literature on cigarette demand, including presenting findings from the senior author's own research (Bickel et al. 1990, 1991; DeGrandpre et al. 1992). As an economist, I am fascinated by this body of work. Although I remain agnostic about the ability to test demand relationships in the laboratory in a manner that will produce important, perhaps policy-relevant insights, my agnosticism reflects my relative unfamiliarity with the method rather than anything specifically problematic about it. I will return to this theme momentarily.

Although I have questions, I am also impressed with the potential of this line of research to go "outside the box" to generate understanding of phenomena we cannot trace in real-world data. Indeed, this is the area where, in my judgment, behavioral economics can and should make truly unique and important contributions.

Let me give two examples. First, we can learn something from these laboratory studies about the effects of large cigarette tax increases. As might be expected, the elasticity studies show much greater price elasticity of demand for large price increases. This is highly relevant in today's policy environment, in which large tax increases have been proposed in several states as well as at the federal government level, yet we have no good econometric evidence on the issue, simply because there have been too few very large tax increases to study. At the moment of this writing, for example, three states are considering proposals to raise their excise taxes by as much as $1 per pack, an amount, well in excess of the largest tax increase ever experienced in the United States, that would raise cigarette prices in these states by 50 percent. Although there is a modest amount of analysis of the effects of large tax increases in other countries, particularly Canada (Hamilton et al. 1997), the analytical literature in the United States covers no tax increases exceeding 25 cents per pack.

Do lab-generated demand curves, such as those described in the authors' paper, reflect the shape of actual market demand curves? This is hard to say. Clearly, their ability to mimic real-world demand is constrained, given the limited variation in demographic characteristics of the experimental subjects, the inability to test complete quitting in the approaches described in the paper, and so on. Nevertheless, this approach still almost certainly produces an improvement in knowledge. The mere fact that virtually all of the laboratory studies—across drugs and across species—yield concave demand curves is a potentially enlightening and helpful contribution. Although many economists would expect to see greatly elevated elasticities as prices rise substantially, reflecting income effects, econometric studies—constrained to real-world price ranges—are unable to confirm this phenomenon, which is testable in the behavioral economics laboratory.

The second example of behavioral economics' potential to go "outside the box" to generate important insights concerns the potential of using economic incentives to encourage less-hazardous means of satisfying nicotine addictions. Ohsfeldt and his colleagues address this with regard to the substitutability of smokeless tobacco for cigarettes. But we would also be interested in the substitution for cigarettes of nicotine replacement therapy (NRT) products, like the nicotine patch and gum.

The authors' interesting study of inferior goods offers some insight into how one could evaluate this phenomenon. The authors provided smokers with two brands of cigarettes of equal nicotine strength, one being the smoker's favorite brand, the other being one the smoker did not like. Puffs on the less-favored brand were priced at one-fifth the cost of puffs on the favored brand. The experimenters varied the subjects' incomes, without changing the prices, to see whether one of the goods would be an inferior good. As one might predict, as income rises, the quantity demanded of the less-favored brand declined, indicating that it was an inferior good.

This kind of study can generate insights into the process whereby one might test the substitutability of other nicotine products for cigarettes. The income elasticity is particularly interesting, given that smokers are disproportionately low-income individuals. As the authors observe, however, currently economic incentives strongly favor cigarettes over NRT products, especially for low-income smokers, because the latter are intentionally available only in large quantities requiring a serious investment and hence commitment to quit. They are priced and packaged in a manner designed to minimize abuse potential. This has the additional effect, however, of discouraging more casual quit attempts, perhaps especially by low-income smokers, as well as discouraging consumption of NRT products in lieu of cigarettes by smokers who are not interested in quitting but would like to reduce their daily exposure to carbon monoxide and tar (Warner, Slade, and Sweanor 1997). What would happen if smokers could buy a small pack of Nicorette gum—a day's supply, for example—for a dollar? The laboratory studies could help to enlighten us on this matter.

Like the econometric studies, the behavioral economics approach clearly has its limitations. They include the following:

1. One cannot evaluate the initiation of tobacco use, for the simple reason that to do so would be deemed unethical.

2. This method is likely not effective for assessing permanent quitting.

3. The method offers a limited ability to evaluate demographic aspects of smoking, due to the time and expense of amassing a large enough number of subjects.

4. It is hard to calibrate prices in the laboratory and in the real world. The authors' approach is essentially tautological and ad hoc: They find the range of response requirements that generates elasticities equivalent to those found in econometric studies.

5. It is not clear that the method permits one to mimic the real-world conditions in which smoking occurs. In the authors' own studies, subjects' intakes of food, alcohol, illicit drugs, and caffeinated beverages are all restricted. This may be necessary for the authors' research purposes, but obviously it fails to mimic actual conditions of tobacco use. Clearly, these assumptions could be altered; but to reflect the myriad circumstances in which smokers consume cigarettes would be very difficult indeed.

6. As these studies are commonly executed, they miss a crucial element of the smoking decision, because researchers do not permit their subjects to take any experimental "income" home with them. It is provided on a use-it-or-lose-it basis (i.e., unused income is returned to the investigators at the end of an experimental session). This eliminates some very important issues of opportunity cost, as cigarette consumption vies with consumption of alternative goods

and services in the real world, producing income effects that are difficult to observe in this experimental setting.

In general, the findings reported by Bickel and Madden are remarkably consistent with those from the econometric literature, but a few are troubling. For example, the authors find that less-educated smokers' demand is more inelastic than that of more-educated smokers. This result is both counterintuitive and contrary to empirical evidence, especially Chaloupka's (1991) work in the United States and Townsend's (1987) in the United Kingdom. The authors see this as reflective of an odd relationship between education and socioeconomic status in their subjects. Nevertheless, it remains disconcerting.

In contrast, the authors express disappointment that they do not find gender differences in elasticity, since these have been reported in some of the econometric studies. There is no obvious theoretical reason to expect them, however. Furthermore, the econometric literature is mixed on this issue and, in my judgment, is itself troublesome when differences are found. Authors never offer explanations for these differences.

Conclusion

I want to close by reiterating the coverage shared by these two papers that I consider most interesting and potentially socially important in terms of understanding our ability to ameliorate the health toll of tobacco through taxes and regulatory policies. This is the issue of the substitution of other products, and of novel smoking behaviors, for conventional smoking behavior. Ohsfeldt et al. have explored the relationship between cigarettes and smokeless tobacco. Bickel and Madden describe the substitution of inferior cigarettes under conditions of severely restricted income. Recently, Evans and Farrelly (1998) concluded that young adults may substitute high-nicotine cigarettes for their regular brands when prices rise.

With a bewildering array of new nicotine delivery devices on the market, or on the drawing board, the ability of smokers to switch to other products, many much less hazardous than cigarettes, is going to grow rapidly. There are over 100 patents outstanding on potential new nicotine delivery devices, ranging from an electrically fired device that mimics a cigarette to injectable nicotine (Davis and Slade 1993; Slade 1997). The ability of pricing and regulatory policies to encourage less-hazardous use of nicotine may be well informed by research like that described in these two papers (Warner et al. 1997).

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Comment on Chapters 1 and 2

Neil E. Grunberg

Cigarette Smoking and Other Tobacco Use: Where Biologic Reductionism Leaves Off

Smoking cigarettes, cigars, and pipes; using smokeless tobacco; and self-administering nicotine via other delivery systems involve powerful behavioral and biological addictive processes similar to the self-administration of many illicit drugs (e.g., cocaine, heroin) (USDHHS 1988). These drugs differ, however, in two important ways. First, tobacco and other nicotine delivery systems currently are legal in the United States. Second, tobacco usually is less expensive than similar amounts of the illegal drugs, particularly considering the costs

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in the broadest sense of risks and consequences of use or sale (e.g., danger in procurement of illegal drugs, imprisonment, fines). Although the biological effects and actions of these different drugs are central to their use and abuse, the financial and societal costs also are relevant. Even the most stalwart reductionist must admit that the use and abuse of legal and illegal drugs differ partially as a result of their legal status and the social context that surrounds them. But a strict biologic reductionism leads to the logical conclusion that economic factors must play only a trivial role in the use and abuse of legal addictive drugs, such as tobacco products.

The papers presented in this conference present a strong case that economic variables can meaningfully and profoundly affect the purchase and use of even the most addictive drugs. The data make a convincing case for market elasticity of addictive drug use, including use of tobacco products. Because manipulation of economic variables may be a fruitful way to reduce use of harmful drugs, it is important to broaden the investigation of economic variables and substance use. Therefore, I offer a few suggestions on possible ways to expand this integrated study. My suggestions draw from various approaches and subfields within psychology to apply to economic and econometric studies of tobacco use.

Psychophysics, Sensation, and Perception Psychology

Weber's (1846) classic work on the perception and psychophysics of sensory stimuli indicated that the ability to discriminate or perceive a change depends on the intensity of the target stimulus and the intensity of the background. For example, a 60-watt light bulb turned on in a dark room appears to be much brighter than does the same light bulb in a brightly lit room. Likewise, the sound of a solo flute in a concert hall is different from the same sound and volume if played on a busy, urban street corner. With regard to economics and drug use, it is worth examining the impact of price changes (stimulus) on drug use in the context of the economic status of the target population and the cost of other goods (background). This principle of just noticeable differences (JND) was extended and formalized by Fechner (1860) such that the relationship between stimulus intensity and the sensation's intensity is related by a logarithmic function. Later, Stevens (1953) determined that this relationship is better described by a mathematical power function. It is worth determining whether the psychophysical algorithms (e.g., Steven's power function or Fechner's logarithmic function) also govern drug use in the context of economic variables. Moreover, further studies of drug use and economics should consider other well-developed concepts in psychophysics such as signal detection theory (Swets, Tanner, and Birdsall 1961) and receiver-operator-characteristic (ROC) curves or isosensitivity functions (Linker, Moore, and Galanter 1964; Kling and Riggs 1971). Consideration of these sophisticated concepts designed to analyze stimuli and perceived changes in stimuli in the context of complex backgrounds might provide order and capture more variance related to costs and drug use.

Another phenomenon worth considering is the differential slope of gains versus losses. Generally, losses of magnitude X have greater effects than do gains of the same magnitude. This phenomenon is apparent in decision making (Kahneman, Slovic, and Tversky 1982) and in cross-modality matching and behavioral actions in response to monetary changes (Galanter and Pliner 1974; Grunberg 1987). It also is apparent in motivated behaviors such as approach-avoidance gradients (e.g., Miller 1971). In light of these gain versus loss differences, it would be useful to examine the effects of perceived and real gains versus losses or perceived losses associated with the procurement of licit and illicit drugs.

Experimental Psychology, Research Methods, and Statistical Analyses

The economic analyses based on large data sets are impressive, but they usually are correlational analyses. It is important to determine causality in order to manipulate variables to reach desired outcomes. Here, empirical, controlled studies provide the gold standard, but they are not the only way to determine causality. Triangulation is possible in which the relationship of variables in different contexts can be used to infer causality (Zajonc 1980). For example, cross-cultural data sets or data sets across time can be used with economic and epidemiological data sets to infer likely causality. In other words, substance use and economic data from different countries during the same period can be compared to reveal more information about the relationship between economics and substance use. Alternatively, similar data within the same country of specific subsamples with different socioeconomic status also is worth evaluating.

Another critical issue to consider with the correlational data sets that are the usual substance of economic analyses is how multiple relevant variables may be involved. Certainly, broad-based analyses of societal behaviors are likely the result of more than one variable. With regard to tobacco use, people smoke or not based on the availability of tobacco, the nicotine content of tobacco products, the nicotine delivery of tobacco products, peer pressures, role models, societal pressures, costs, and so on. But how do these many variables jointly contribute to tobacco use? To evaluate each variable separately is conceptually and statistically incorrect. Even to evaluate all potentially relevant variables in a simultaneous multivariate analysis may be limited or wrong. For example, if several variables interact to have a meaningful effect, then this fact would be revealed only if the interaction term also was included in the analyses. More complicated, however, is the case in which a given variable(s) mediates the action of another variable. Even more complicated is the case in which a given variable(s) moderates the actions of other variables and alters their effects. Various multivariate analyses, path analyses, and structural equation analyses can begin to address these scenarios, but investigators must carefully select and consider how to properly analyze complex data sets (Loehlin 1987; Marcoulides and Schumacker 1996). Further, it is important to consider the possibilities of type I (false negative) and type II (false positive) errors and how selection of analytic strategies and confidence intervals contribute to or attenuate these problems (Cohen and Cohen 1983). All of these issues are soluble, but careful consideration must be given to the selection of appropriate multivariate analyses.

Curvilinear Functions

Another issue that comes to mind based on the papers presented at this meeting has to do with curvilinear functions, in general, and U-shaped (or inverted U-shaped) functions, in particular. It is a common and well-recognized error to assume that monotonic linear functions are the underlying functions of interpolation and extrapolation. Instead, the missing values may follow a curvilinear function. This possibility should be recognized and examined.

It is not as common to realize that a simple curvilinear function (such as a U or inverted U) may result from two different underlying phenomena: (i) there truly is a curvilinear function; or (ii) the apparent curvilinear function is a result of the combination of two opposing monotonic linear functions. It is important to consider these differences because one is based on a single function, whereas the other is based on two different functions that might change under different individual variables or that might be manipulated in different ways.

Social Psychological Principles

Economic analyses of variables related to the use and abuse of tobacco and other addictive substances approximate social psychology (the study of mind and behavior of individuals within the context of groups) perhaps more than any other speciality in psychology. In this context, it is relevant to cite and consider the work of Kurt Lewin (1938, 1951), who presented the overarching formula that behavior is a function of the person and his or her environment, or $B = f(P, E)$. The person includes every aspect of the individual, including genotype, personality, motivations, drives, talents, abilities, thoughts, beliefs, attitudes, opinions, appearance, and so on. The environment includes the broadest definition of one's surroundings, including, among others, the physical, social, cultural, societal, and economic, aspects. In this sense, any consideration of behavioral economics should look to Lewin and his professional dynasty of students' work (including the work of Leon Festinger, Stanley Schachter, Morton Deutsch, Harold Kelly, and their students). There are vast literatures relevant to behavior and economics from this professional line, including work on group dynamics, behaviors of individuals in groups, leadership, and peer influences (Festinger 1980). Moreover, the study of behavior and economics would profit from consideration of work on attitudes and behaviors (Hovland, Janis, and Kelley 1953; Hovland and Rosenberg 1960), as well as consideration of gender and other individual difference variables that are relevant to the use and abuse of various drugs and in social contexts.

Synopsis

Economic analyses of substance abuse on societal and laboratory levels offer valuable information and insights into important behaviors and problems. The work presented at this conference indicates that there already are relevant data from economic analyses of large data sets and from laboratory investigations with human and animal subjects. This conference and the papers presented make clear just how valuable it is for economic and social scientists to discover each other's work and to communicate. I hope that this dialogue is just a beginning and that my suggestions help move this cooperation forward.

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II Alcohol Use and Abuse