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8 A Behavioral Economic Analysis of Polydrug Abuse in Heroin Addicts

Nancy M. Petry and Warren K. Bickel

Alcoholics and illicit drug users often consume a wide variety of drugs (Ball and Ross 1991; Hubbard et al. 1989; Hammersley, Forsyth, and Lavelle 1990). For example, 50, 33, 47, and 69 percent of heroin addicts applying for methadone treatment are regular users of alcohol, benzodiazepines, cocaine, and marijuana, respectively (Ball and Ross 1991). Prevalence of marijuana use among cocaine- and alcohol-dependent patients ranges from 25 to 70 percent (Higgins et al. 1991; Hubbard 1990; Miller, Gold, and Pottash 1989; Schmitz et al. 1991). Polydrug abuse presents a range of problems to treatment and public health initiatives. For example, the overwhelming majority of drug-related hospital emergency room visits involve combinations of alcohol and multiple illicit drug use (NIDA 1991). Polydrug abuse also increases likelihood of overdose (Risser and Schneider 1994; Ruttenber and Luke 1984), HIV risk-taking behavior (Darke et al. 1994; Klee et al. 1990), and poor treatment compliance (e.g., Ball and Ross 1991).

One problem in trying to understand polydrug abuse is that no descriptive method has been designed to characterize it. For example, polydrug abuse refers to the use of two drugs together (e.g., "speedball") and the use of drugs in place of one another (e.g., using barbiturates or benzodiazepines when alcohol is not available). An understanding of variables that affect the use of different drugs may elucidate factors that precipitate and propagate drug abuse and dependence.

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8.1 Behavioral Economic Analysis and Its Putative Relationship to Polydrug Abuse

Price is one variable that seems intricately related to drug use. Economists are devoted to the proposition that higher prices will lower consumption of almost any good (e.g., Mansfield 1988), and considerable evidence suggests that drug consumption responds to changes in price. For example, alcohol and nicotine use both decrease as their respective prices increase (e.g., Becker, Grossman, and Murphy 1994). The interrelationship between price and consumption of illicit drugs, however, has been difficult to assess. Because drugs are bought and sold in a volatile market and in varying purities, very little data exist on how prices affect polydrug abuse in natural settings. In particular, how the price of one drug may affect the use of other drugs is not well understood.

Behavioral economics is an analytic research area that applies consumer demand theory to the study of behavior, and these theories have been applied successfully to drug dependence issues in laboratory experiments of drug self-administration (e.g., Bickel et al. 1990, 1991, 1995; DeGrandpre et al. 1993). *Cross-price elasticity* (E_{cross}) can be determined using equation (1) derived from Allison (1983):

$$(1) \qquad E_{cross} = (\log Q_{A2} - \log Q_{A1})/(\log P_{B2} - \log P_{B1}),$$

where Q is quantity consumed of reinforcer A at price $B1$ or $B2$. Positive E_{cross} values indicate that reinforcer A is a substitute for reinforcer B, and negative E_{cross} values indicate that reinforcer B is a complement of reinforcer A. Values around 0 indicate that reinforcer A is independent of reinforcer B (Bickel, DeGrandpre, and Higgins 1995; Green and Freed 1993; Hursh 1980, 1991, 1993; Samuelson and Nordhaus 1985).

Own-price elasticity (E_{own}) can be calculated using an equation from Allison (1983):

$$(2) \qquad E_{own} = (\log Q_{A2} - \log Q_{A1})/(\log P_{A2} - \log P_{A1}),$$

where Q is the quantity of reinforcer A purchased at price (P) 1 or 2. When price and consumption data are plotted on log-log coordinates, the slope between any two points represents E_{own}, with slopes < -1 representing elastic demand and slopes > -1 representing inelastic demand (e.g., DeGrandpre and Bickel 1996; DeGrandpre, et al. 1994; Hursh 1980, 1991, 1993; Samuelson and Nordhaus 1985).

Elasticity can also be assessed by examining consumption following income manipulations. *Income elasticities* (E_{inc}) can be determined from equation (2), with P being income. Values of E_{inc} greater than 1 are indicative of elastic demand, with purchases rising in greater proportion than the rise in income. Values of E_{inc} less than 1 are indicative of income inelastic demand, with purchases not rising in proportion to income. When consumption and income are plotted on log-log coordinates, income elastic demand is demonstrated by a slope of ≥ 1 and income inelastic demand by a slope of < 1 (DeGrandpre et al. 1993).

These concepts of cross-price, own-price, and income elasticities have been tested empirically in laboratory experiments of drug self-administration. Bickel, DeGrandpre, and Higgins (1995) reviewed 16 studies in which two reinforcers, one or both of which were drugs, were concurrently available and prices (usually in terms of the number of lever presses required for a unit of drug) were altered. Cross-price elasticities indicated that some drugs were substitutes for others, some served as complements, and others were independents. For example, in a group of rhesus monkeys responding for concurrently available alcohol and PCP, increases in response requirements for PCP resulted in an increase in responding for and consumption of alcohol (Carroll 1987). Thus, alcohol was a substitute for PCP. In terms of complements, both heroin and cigarette self-administration decreased when the price of heroin rose, indicating that cigarettes were a complement to heroin (Mello et al. 1980a). Cigarette smoking also decreased as alcohol price rose in the majority of subjects in one study (Mello et al. 1980b), but cigarette smoking was relatively independent of alcohol price in another study (Mello, Mendelson, and Palmieri 1987). Bickel et al. (1992) found that cigarette smoking and coffee consumption were independent, regardless of whether the response requirement was raised for cigarettes or coffee. The relationship between concurrently available drug reinforcers was not always symmetrical, however. Although ethanol substituted for PCP when the lever press requirement for PCP was raised, increases in the response requirement for ethanol did not affect PCP self-administration (Carroll 1987).

In terms of own-price elasticities, demand for alcohol was relatively inelastic compared to demand for sucrose in rats with extensive alcohol histories (Heyman and Oldfather 1992; Petry and Heyman 1995). Thus, responding for alcohol persisted and increased as the response requirement for alcohol rose, while responding for and consumption of sucrose rapidly diminished when its response requirements rose. Similarly, demand was inelastic for etonitazene (Carroll and Meisch 1979), morphine (Dworkin et al. 1984), PCP (Carroll, Carmona, and May 1991), coffee (Bickel et al. 1992), and nicotine (Bickel et al. 1992) at some increases in price for these various drugs. However, at large price increases, demand for these drugs often became elastic, and consumption decreased proportionally greater than rises in price.

Income can be defined as the amount of funds, goods, or services available to any one individual at a given time (Pearce 1986). In behavioral terms, income can be conceptualized as a constraint on total reinforcement possible to earn in a laboratory session (e.g., total allotted time to respond or total number of responses available). Increases in income can either increase or decrease the choice of any particular good, depending on the type of good and the availability of other goods (Deaton and Muellbauer 1980; Lea, Tarpy, and Webley

1987). For example, choice for a large, bitter food pellet increased relative to a small, normal pellet when income was decreased (Silberberg, Warren-Boulton, and Asano 1987). Only one known laboratory study has examined directly the effects of income on drug self-administration. DeGrandpre et al. (1993) varied the amount of income available during experimental sessions, while prices remained constant. Subjects were nicotine-dependent smokers, and they could purchase puffs on their preferred brand of cigarettes or on a less-preferred brand of cigarettes during the sessions. Puffs on the less-preferred brand were less expensive than puffs on the preferred brand. In low-income conditions, subjects purchased more puffs from the normally nonpreferred brand. As income increased, puffs on the preferred brand increased, and demand for the preferred cigarettes was income elastic (DeGrandpre et al. 1993).

These economic relationships of cross-price, own-price, and income elasticities may be useful in describing and predicting drug use in natural situations as well as in these laboratory settings (Bickel and DeGrandpre 1995, 1996; Hursh 1991). For example, as heroin price increases, heroin addicts may substitute less expensive opioids (methadone) or drugs from other classes that abate opioid withdrawal symptoms (e.g., benzodiazepines). Demand for drugs that produce physical dependence may be relatively inelastic among dependent individuals, with increases in price not greatly affecting consumption. Analysis of income elasticity of demand may show that as one has more disposable money, consumption of certain drugs (e.g., heroin and cocaine) may increase markedly, while consumption of other drugs may remain relatively constant (e.g., marijuana).

8.2 Description of Simulation Methodology

Systematic investigation of the relationship between price and polydrug abuse in natural settings is hindered by the illicit nature of many drugs of abuse. Drugs are bought at fluctuating prices and variable purities. While these relationships can be studied in the laboratory, logistical and ethical considerations of providing drugs to drug abusers remain. Behavioral simulation experiments involve simulation of essential aspects of a situation in order to elicit the behavior in question. If behavior that emerges in the simulation is similar to that observed in natural situations, then processes responsible for the behavior have likely been identified (Epstein 1986). Such simulations have been used successfully in experimental economics such that resultant data is predictive of behavior in the real world (Plott 1986).

This chapter describes a behavioral simulation paradigm that was developed to apply a behavioral economic analysis to the phenomena of polydrug abuse (Petry and Bickel 1998). Polydrug abusing heroin addicts were given imitation money, and prices of drugs were indicated on paper. Subjects indicated the types and quantities of drugs they would buy, presuming they had the available amount of money to spend. Changes in drug choices were examined as a function of price and money available.

The subjects were 40 patients in our outpatient programs for opioid abuse and dependence. Of those enrolled in the clinic, 96 percent volunteered, and therefore the sample tested was representative of our clinic population. Fifteen subjects were female, and 25 were male. On average, subjects were in treatment for 3.8 months (range 3 weeks to 16 months). Thirty-two of the subjects were receiving buprenorphine (an alternative to methadone), five were receiving naltrexone (an opioid antagonist that prevents relapse to opioid abuse), and three were no longer receiving medication. One subject was receiving Antabuse. Average age was 35, and average years of education was 12. Average legal monthly income was $750, and in the month prior to intake, subjects used an average of $350 worth of opioids each week. On average, subjects reported a 10-year history of heroin dependence, and intravenous use was the route of choice for all but 6 subjects, who used heroin intranasally. In the month prior to intake, 65, 68, 60, and 55 percent of subjects reported alcohol, benzodiazepine, cocaine, and marijuana use, respectively.

A sample of the stimuli used for these experiments is shown in appendix figure 8A.1. Various drugs, in amounts typically used for a "hit," are presented. The prices are representative of Vermont street prices, as determined by informal survey. A copy of the imitation money used in these studies is shown at the bottom of the figure. The experiment commenced with the experimenter reading instructions that subjects were to presume that they were not in treatment and were actively abusing drugs. Subjects were also told that they had a certain amount of "money" that they could "spend" on drugs each day, and that they could not receive drugs from any other source, other than those they "bought" with the allotted money. The subjects were further instructed to presume that the drugs they "purchased" were for their own personal consumption only, and that all drugs "purchased" in this hypothetical situation could only be used in a 24-hour period. They were told that they could not "sell" drugs that they "purchased" or save them up for later.

8.2.1 Effects of Heroin Price on Demand for Heroin, Valium, Cocaine, Marijuana, and Alcohol

In experiment 1 (Petry and Bickel 1998), we examined the cross-price elasticities of demand for valium, cocaine, alcohol, and marijuana using equation (1), and the own-price elasticity of demand for heroin using equation (2). Four trials were presented in which heroin prices varied between the trials; heroin was available at $3, $6, $11, and $35 per bag. Income was kept constant at $30 per trial, and prices of valium, cocaine, alcohol, and marijuana remained constant at local street prices: valium was $1 per pill, cocaine was $15 per 1/8 ounce, alcohol was $1 per drink, and marijuana was $5 per joint.

The top panel of figure 8.1 shows heroin purchases as a function of heroin price. Statistical analyses indicated that heroin purchases differed significantly

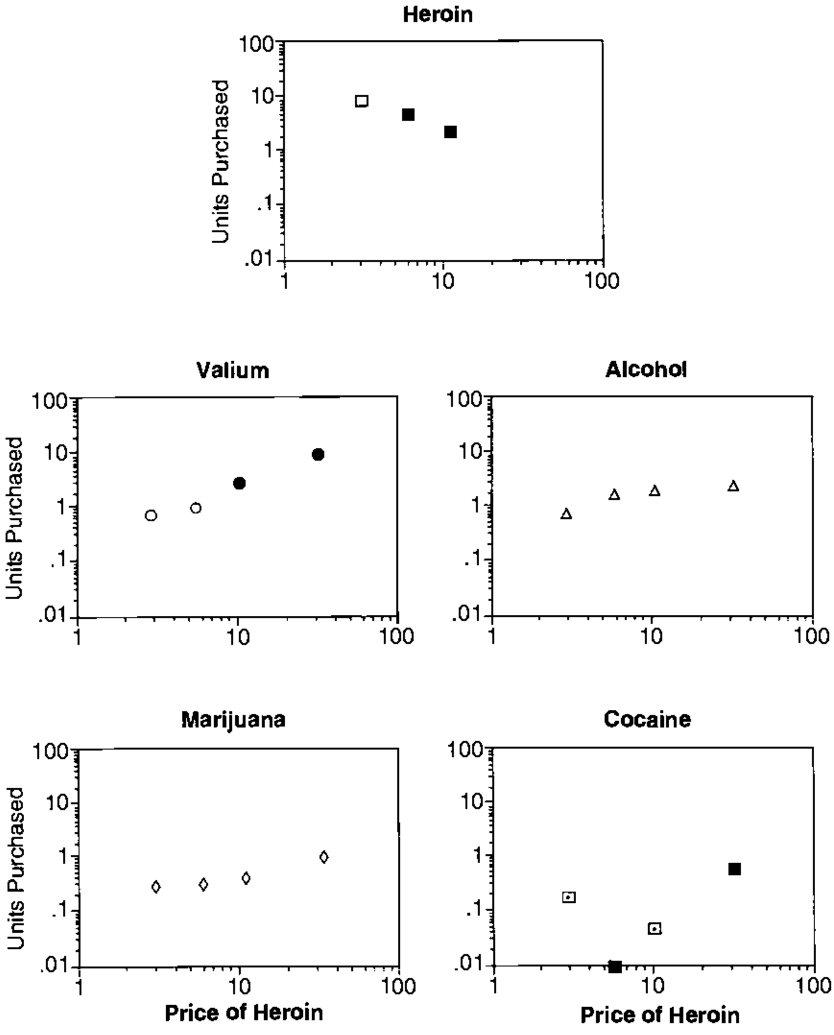

Fig. 8.1 Mean units of heroin, valium, alcohol, marijuana, and cocaine purchased as heroin increases in price from $3 to $35 per bag

Note: Data are plotted in log-log coordinates such that the slope between any two successive points is equal to the E_{own} or E_{cross} values listed in table 8.1. Purchases that differ significantly from the $3 heroin price condition are denoted by solid symbols. No heroin purchases were made in the $35 heroin price condition since price exceeded income, and therefore no symbol is plotted for heroin in this condition. See text for further details.

across the three price conditions in which heroin could be purchased, and values significantly different from the $3 condition are denoted by solid symbols. Note that across all conditions, subjects tended to spend a large proportion of their $30 income on heroin. In the $3 price condition, the mean number of bags of heroin purchased was over eight; in the $6 condition, mean purchases

Table 8.1 **Own-Price Elasticity Coefficients of Heroin and Cross-Price Elasticity Coefficients of Other Drugs Determined from Mean Units Purchased**

Heroin Price ($ per bag)	Heroin	Valium	Alcohol	Marijuana	Cocaine
3					
6	−0.861	0.380	1.311	0.000	−4.170
11	−1.258	1.686	0.188	0.409	2.655
35	—	1.015	0.181	0.726	2.203
Slope of best-fitting line	−1.042	1.056	0.451	0.464	0.822

was just under five bags; and in the $11 condition, mean purchases was two bags.

Data are plotted on log-log coordinates, such that the slope between any two successive points is equal to the E_{own} values shown in table 8.1. As heroin increased in price from $3 to $6, the own-price elasticity of demand was −.86. This value suggests that demand for heroin was inelastic, and increases in price were associated with decreases in purchases that were proportionally smaller than the price increments. Demand for heroin became more elastic as its price increased further, from $6 to $11, with own-price elasticity of demand equal to −1.26.

The top panel of figure 8.2 shows the percent of subjects demonstrating elastic and inelastic demand for heroin as its price rose. When heroin doubled in price from $3 to $6, over 85 percent of subjects showed inelastic demand for heroin, but as price increased further to $11 and $35, demand for heroin became elastic in the majority of subjects.

The price of heroin affected not only heroin purchases but purchases of other drugs as well. When heroin was inexpensive, subjects tended not to purchase valium, and the average number of valium pills purchased was less than 1 (fig. 8.1). However, as heroin price rose, valium purchases significantly increased, and the number of valium pills purchased in the $11 and $35 heroin conditions differed significantly from the number of pills purchased in the $3 heroin condition. In the $35 heroin price condition, for example, subjects purchased an average of 10 valium pills. E_{cross} values for valium were high, ranging from .38 to 1.69, with an overall slope of 1.06, indicative of a strong substitution effect (table 8.2). Figure 8.2 shows that approximately 50 percent of subjects substituted valium for heroin as heroin prices rose.

Average alcohol and marijuana purchases also increased, but not significantly, with heroin price. In low heroin price conditions, the average number of alcoholic drinks and marijuana joints purchased was less than one. As heroin price rose, purchases of these drugs increased, but the mean number of drinks and joints purchased was under three, even in the condition in which subjects were unable to buy heroin (heroin = $35). E_{cross} values averaged about 0.5 for both marijuana and alcohol, indicative of a relatively independent or weak substitute relationship. Figure 8.2 shows that marijuana and alcohol purchases

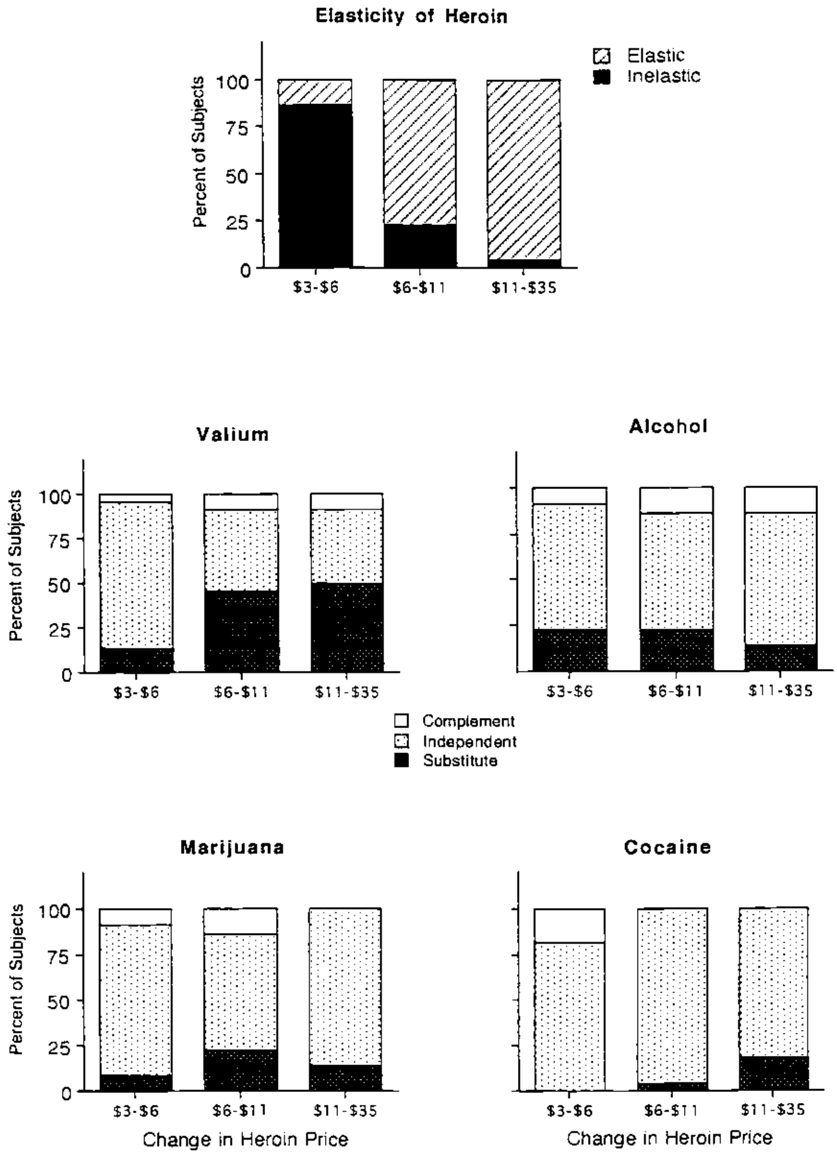

Fig. 8.2 Percent of subjects demonstrating own- and cross-price demand elasticities

Note: This figure shows the percentage of subjects demonstrating inelastic or elastic demand for heroin as the price of heroin increased in experiment 1, and the percentage of subjects demonstrating a complement, independent, or substitution relationship between valium, marijuana, alcohol, and cocaine purchases as heroin price increased in experiment 1. See text for further details.

Table 8.2 Elasticity Coefficients for Mean Units Purchased as Heroin Price Increases

Heroin Price ($ per bag)	Valium Price ($ per pill)	Own-Price Heroin	Cross-Price Valium	Cross-Price Marijuana	Cross-Price Alcohol
3	0.33	—	—	—	—
6	0.33	−0.897	−0.678	−0.735	−0.322
11	0.33	−1.317	2.502	0.841	1.263
35	0.33	—	0.986	1.576	1.038
Slope of best-fitting line		−1.088	1.024	0.819	0.780
3	1	—	—	—	—
6	1	−0.923	0.186	−0.325	−0.651
11	1	−1.232	1.217	0.371	1.220
35	1	—	1.252	1.518	0.438
Slope of best-fitting line		−1.064	0.990	0.746	0.403
3	3	—	—	—	—
6	3	−0.874	0.416	−1.000	−1.469
11	3	−1.322	0.842	2.069	1.923
35	3	—	1.328	1.338	0.223
Slope of best-fitting line		−1.064	0.990	0.746	0.403
3	10	—	—	—	—
6	10	−0.904	0.000	−0.996	−0.214
11	10	−1.233	2.953	1.613	1.834
35	10		0.234	1.199	0.254
Slope of best-fitting line		−1.054	0.929	0.797	0.594

were independent of heroin price in the majority of subjects across all heroin price conditions.

In contrast to the lack of a significant effect on alcohol and marijuana purchases, cocaine purchases were significantly affected by heroin price. As denoted by filled symbols in figure 8.1, the number of cocaine purchases in the $6 and $35 heroin conditions was significantly different from the number of purchases in the $3 heroin condition. Cocaine was a complement when heroin price increased from $3 to $6 per bag, but it became a substitute as heroin price continued to rise (table 8.1). While the group mean purchases demonstrated this complement and substitution effect as heroin price rose, this effect occurred in only 23 percent of subjects (fig. 8.2). In the majority of subjects, demand for cocaine was independent of heroin price.

8.2.2 Symmetry of Substitutability of Heroin and Valium

Effect of Heroin Price on Demand for Valium, Alcohol, and Marijuana

In experiment 2 (Petry and Bickel 1998), we altered the prices of both heroin and valium to determine whether cross-price elasticities between these two drugs were symmetrical or asymmetrical. This experiment contained 16 conditions, presented in a random order to 18 subjects. Heroin prices varied ($3, $6, $11, and $35 per bag), and at each heroin price condition, valium was available at $0.33, $1, $3, and $10 per pill. Income was constant at $30, and marijuana and alcohol prices were $5 and $1, respectively. In addition to providing cross-price elasticities, this study provided estimates of the own-price elasticity of demand for valium in heroin addicts. This experiment also provided estimates of the own-price elasticity of demand for heroin when cocaine was not available and in a new group of subjects, none of whom participated in study 1.

Figure 8.3 shows drug purchases as heroin price increased in experiment 2. Four panels are shown, one for each valium price condition. Statistical analyses demonstrated that valium purchases were significantly affected by heroin price. In conditions in which valium was inexpensive, subjects purchased large

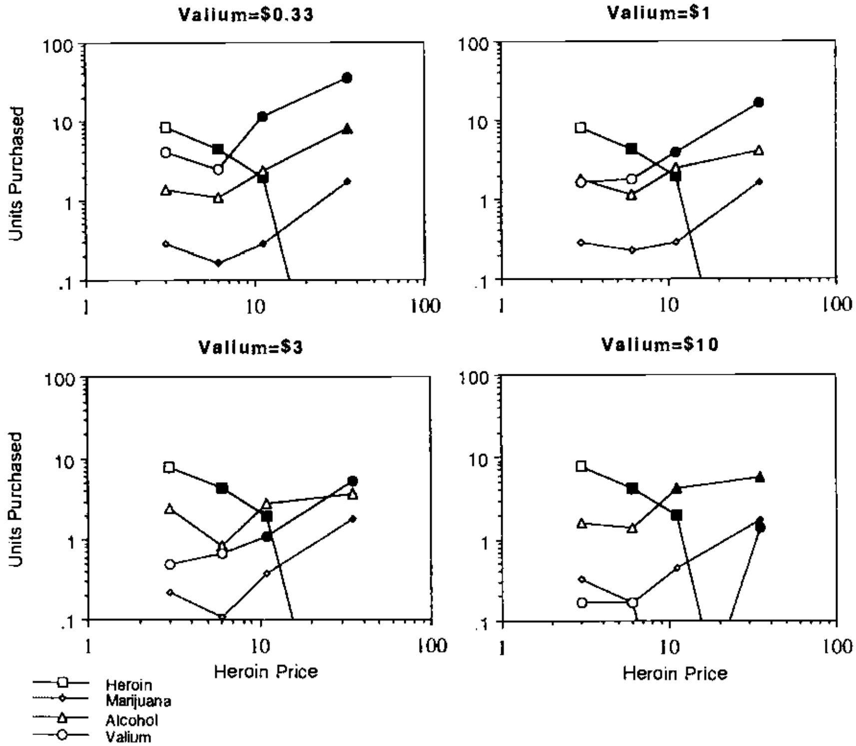

Fig. 8.3 Mean units of heroin, valium, alcohol, and marijuana purchased as heroin price increases from $3 to $35 per bag

Note: Panels show this data for the $0.33, $1, $3, and $10 valium price conditions. Purchases that differ significantly from the $3 heroin price condition are denoted by filled symbols. No heroin purchases were made in the $35 heroin price condition since price exceeded income, and therefore no symbol is plotted for heroin in this condition. See text for further details.

quantities of valium, with an average of 4 pills purchased even when they concurrently purchased eight bags of heroin. As heroin price rose to $35 per bag, valium purchases increased to an average of 40 and 20 pills in the $0.33 and $1 valium price conditions, respectively. While the quantities of valium purchased were lower in conditions in which valium was more expensive ($3 and $10 per pill), valium purchases nevertheless increased significantly as heroin price rose (range from less than 1 to over 6 pills).

Table 8.2 shows cross-price elasticity values for valium as heroin price rose. Regardless of the price of valium, E_{cross} values indicated that demand for valium was relatively independent of heroin price when heroin price increased from $3 to $6 per bag. However, as heroin prices increased further to $11 and $35, valium tended to become a strong substitute for heroin, with cross-price elasticities ranging from .23 to 1.32. Across the four heroin price conditions, the overall cross-price elasticities for valium ranged from .93 to 1.02. These values are indicative of a strong substitute relationship between valium purchases and heroin prices.

Table 8.3 shows the percentage of subjects demonstrating a substitution, complement, or independent relationship between heroin price and valium purchases. In the majority of subjects, valium purchases were generally independent of heroin price when heroin was inexpensive ($3 to $6). However, valium became a substitute for heroin in the majority of subjects as heroin prices increased further. Over half of the subjects substituted valium for heroin at some or all of the different valium price conditions as heroin prices rose.

Heroin price also significantly affected purchases of marijuana in some conditions (fig. 8.3). E_{cross} values for marijuana were negative ($-.325$ to -1.0) as heroin rose from $3 to $6, indicating that marijuana was an independent or complement to heroin when the price of heroin was relatively low. As heroin prices increased further, E_{cross} values were positive, indicating that marijuana became a substitute for heroin. Table 8.3 shows that approximately 30 percent of subjects substituted marijuana for heroin in high heroin price conditions, but the majority of subjects showed an independent relationship between heroin price and marijuana purchases.

Similar to marijuana, E_{cross} values for alcohol were negative as heroin increased from $3 to $6, indicating that alcohol was an independent or complement to heroin. As the price of heroin increased further to $11 and $35 per bag, alcohol purchases rose slightly, with elasticities ranging from .223 (independent) to 1.923 (strong substitute). Only in the conditions in which valium was very inexpensive ($0.33) or very expensive ($10) did alcohol purchases significantly increase with heroin price. Approximately 70 percent of subjects showed an independent relationship between heroin price and alcohol purchases (table 8.3).

Similar to experiment 1, heroin purchases significantly decreased as heroin price increased (fig. 8.3). E_{own} values for heroin were remarkably similar regardless of valium price (table 8.2). Over 75 percent of the subjects showed

Table 8.3 **Percent of Subjects Demonstrating Inelastic or Elastic Demand for Heroin and Cross-Price Elasticities for Other Drugs**

Heroin Price	Heroin		Valium			Marijuana			Alcohol		
($ per bag)	Inelastic	Elastic	Substitute	Independent	Complement	Substitute	Independent	Complement	Substitute	Independent	Complement
					Valium = $0.33 per pill						
3–6	88.9	11.1	11.1	66.7	22.2	0.0	94.4	5.6	11.1	83.3	5.6
6–11	11.1	88.9	61.1	33.3	5.6	16.7	77.8	5.6	27.8	72.2	0.0
11–35	0.0	100.0	38.9	55.6	5.6	33.3	66.7	0.0	22.2	72.2	5.6
					Valium = $1 per pill						
3–6	77.8	22.2	16.7	66.7	16.7	0.0	94.4	5.6	11.1	83.3	5.6
6–11	22.2	77.8	50.0	38.9	11.1	16.7	72.2	11.1	22.2	77.8	0.0
11–35	0.0	100.0	61.1	33.3	5.6	38.9	61.1	0.0	11.1	72.2	16.7
					Valium = $3 per pill						
3–6	88.9	11.1	5.6	83.3	11.1	0.0	88.9	11.1	0.0	77.8	22.2
6–11	16.7	83.3	44.4	44.4	11.1	27.8	72.2	0.0	38.9	50.0	11.1
11–35	5.6	94.4	55.6	44.4	0.0	33.3	66.7	0.0	5.6	83.3	11.1
					Valium = $10 per pill						
3–6	88.9	11.1	5.6	88.9	5.6	0.0	88.9	11.1	22.2	66.7	11.1
6–11	22.2	77.8	0.0	88.9	11.1	33.3	61.1	5.6	44.4	50.0	5.6
11–35	0.0	100.0	55.6	44.4	0.0	27.8	72.2	0.0	5.6	61.1	33.3

inelastic demand for heroin when its price increased from $3 to $6 (table 8.3), but the majority of subjects demonstrated elastic demand for heroin as prices for heroin increased further.

Effect of Valium Price on Demand for Heroin, Alcohol, and Marijuana

Figure 8.4 shows the same data from experiment 2, but as a function of valium price. The four panels show the number of drug purchases at each heroin price condition. Heroin purchases were not significantly affected by the price of valium. In contrast to the substitution effect of valium for heroin, table 8.4 shows that E_{cross} values for heroin were extremely small (0.000 to −0.047) when valium prices rose. Thus, heroin purchases were independent of valium prices. Likewise, alcohol and marijuana purchases did not vary significantly with valium price. E_{cross} values for alcohol and marijuana were small, indicating that purchases of these substances were independent of valium price as well.

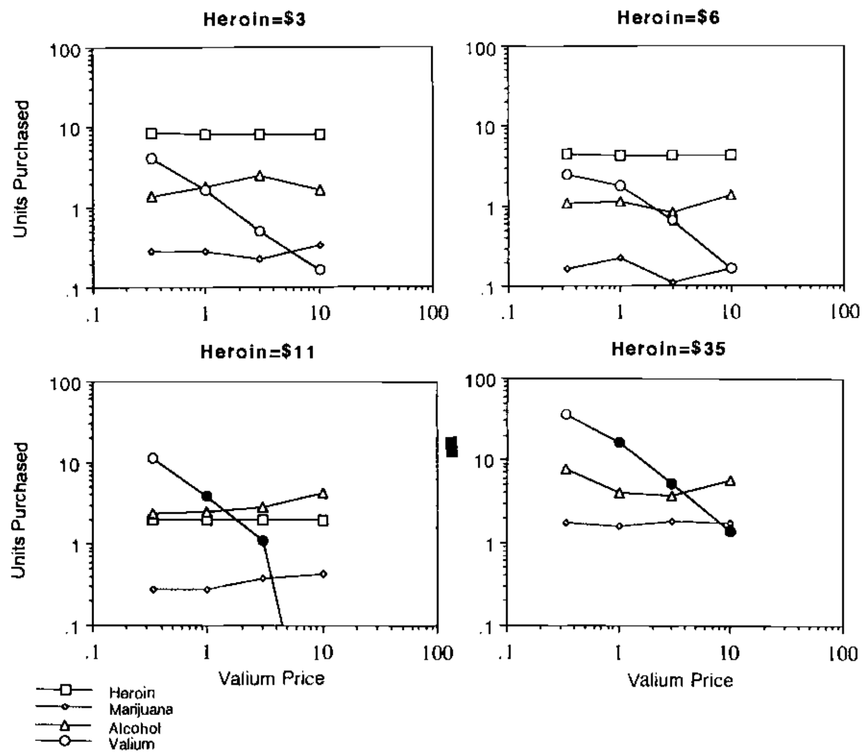

Fig. 8.4 Mean units of heroin, valium, alcohol, and marijuana purchased as valium price increases from $0.33 to $10 per pill

Note: Panels show this data for the $3, $6, $11, and $35 heroin price conditions. Purchases that differ significantly from the $0.33 valium price condition are denoted by filled symbols. No heroin purchases were made in the $35 heroin price condition since price exceeded income, and therefore no symbol is plotted for heroin in this condition. See text for further details.

Table 8.4 **Elasticity Coefficients for Mean Units Purchased as Valium Price Increases**

Valium Price ($ per Pill)	Heroin Price ($ per Bag)	Own-Price Valium	Cross-Price Heroin	Cross-Price Marijuana	Cross-Price Alcohol
0.33	3	—	—	—	—
1	3	−0.820	−0.031	0.000	0.250
3	3	−1.065	−0.006	−0.205	0.262
10	3	−0.911	−0.006	0.337	−0.346
Slope of best-fitting line		−0.944	−0.013	0.300	0.061
0.33	6	—	—	—	—
1	6	−0.280	−0.047	0.257	0.044
3	6	−0.920	0.024	−0.631	−0.307
10	6	−1.150	−0.022	0.339	0.425
Slope of best-fitting line		−0.809	−0.011	−0.059	0.032
0.33	11	—	—	—	—
1	11	−0.982	0.000	0.000	0.021
3	11	−1.128	−0.026	0.306	0.134
10	11	−7.737	0.024	0.110	0.331
Slope of best-fitting line		−1.055	−0.002	0.154	0.165
0.33	35	—	—	—	—
1	35	−0.705	—	−0.060	−0.606
3	35	−1.047	—	0.118	−0.092
10	35	−1.091	—	−0.025	0.362
Slope of best-fitting line		−0.962	—	0.020	−0.094

Table 8.5 shows the percentage of subjects demonstrating a substitution, complement, or independent relationship between valium price and purchases of heroin, alcohol, and marijuana. Heroin purchases were independent of valium price in every subject across all conditions studied. Marijuana and alcohol purchases also tended to be independent of valium price in most subjects. Only in one condition (heroin at $11 per bag, and valium increasing from $3 to $10) did one-third of the subjects demonstrate a substitution effect of alcohol for valium.

Although the price of valium did not significantly affect purchases of heroin, marijuana, or alcohol, figure 8.4 shows that valium price significantly affected valium purchases. As valium prices rose, valium purchases decreased. Table 8.4 shows that demand for valium was inelastic with initial changes in valium price ($0.33 to $1 per pill), but demand for valium became more elastic as its price increased further, and the slopes between price conditions tended to be less than −1. Table 8.5 also shows the percentage of subjects demonstrating inelastic and elastic demand for valium. Across all conditions, demand for valium was inelastic in over half of subjects.

Table 8.5 **Percent of Subjects Demonstrating Inelastic or Elastic Demand for Valium and Cross-Price Elasticities for Other Drugs**

Valium Price	Valium		Heroin			Marijuana			Alcohol		
($ per Pill)	Inelastic	Elastic	Substitute	Independent	Complement	Substitute	Independent	Complement	Substitute	Independent	Complement
					Heroin = $3 per bag						
0.33–1	94.4	5.6	0.0	100.0	0.0	0.0	100.0	0.0	5.6	94.4	0.0
1–3	83.3	16.7	0.0	100.0	0.0	0.0	100.0	0.0	5.6	94.4	0.0
3–10	94.4	5.6	0.0	100.0	0.0	0.0	100.0	0.0	0.0	88.9	11.1
					Heroin = $6 per bag						
0.33–1	94.4	5.6	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0
1–3	88.9	11.1	0.0	100.0	0.0	0.0	100.0	0.0	0.0	94.4	5.6
3–10	88.9	11.1	0.0	100.0	0.0	0.0	100.0	0.0	11.1	88.9	0.0
					Heroin = $11 per bag						
0.33–1	72.2	27.8	0.0	100.0	0.0	0.0	100.0	0.0	5.6	83.3	11.1
1–3	55.6	44.4	0.0	100.0	0.0	0.0	100.0	0.0	16.7	72.2	11.1
3–10	72.2	27.8	0.0	100.0	0.0	0.0	100.0	0.0	33.3	66.7	0.0
					Heroin = $35 per bag						
0.33–1	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	77.8	22.2
1–3	55.6	44.4	0.0	100.0	0.0	5.6	94.4	0.0	16.7	77.8	5.6
3–10	61.1	38.9	0.0	100.0	0.0	5.6	88.9	5.6	5.6	88.9	5.6

8.2.3 Effects of Income on Demand for Drugs

In experiment 3 (Petry and Bickel 1998), we examined income elasticities by varying the amount of money available: $30, $100, $156, $300, and $560. Prices were constant at all conditions: heroin was $35 per bag, valium was $1 per pill, marijuana was $5 per joint, alcohol was $1 per drink, and cocaine was $15 per 1/8 ounce. The same 22 subjects who participated in experiment 1 participated in this study. Thus, a total of nine conditions (the four heroin price conditions from experiment 1, and the five income conditions from experiment 3) were presented in a random order to each of these subjects.

Increases in income were associated with statistically significant increases in the total number of bags of heroin purchased, as shown in figure 8.5. When subjects had $100 available, they purchased an average of 1.7 bags of heroin. As income increased to $156, an average of 3 bags of heroin was purchased. In the $560 income condition, subjects purchased an average of over 10 bags of heroin. Income elasticity coefficients were high for heroin (table 8.6). An increase in income from $100 to $156 was associated with a steep rise in heroin purchase (slope = 1.58), indicative of an income elastic demand for heroin. But as income increased further, the slope of the line between successive incomes became slightly lower, and demand for heroin became income inelastic. The slope of the best-fitting line between the four conditions in which heroin could be purchased, however, was greater than 1 and indicative of an income elastic demand for heroin.

Income did not significantly affect valium purchases. The income elasticity coefficients for valium were negative in the conditions in which subjects received a relatively low income, demonstrating a nonsignificant decrease in valium purchases at initial increases in income. The slope of the best-fitting line across all income conditions was close to 0, indicating that overall income did not affect valium purchases. Marijuana purchases showed a similar trend, but again income did not significantly affect purchases. Alcohol purchases likewise increased marginally, but not significantly, with each successive increase in income.

Cocaine purchases, however, increased significantly with income (fig. 8.5), and demand for cocaine was income elastic in the two highest income conditions (table 8.6). The slope of the best-fitting line between the four income levels was positive (.71) but less than that of heroin. Thus, over the five income conditions tested, income significantly affected cocaine purchases, but demand for cocaine was income inelastic overall.

Figure 8.6 shows the percentage of subjects showing income elastic or income inelastic demand for each drug across the income levels. At each successive increase in income, over 50 percent of the subjects demonstrated income elastic demand for heroin, suggesting that heroin purchases increased proportionally greater than rises in income. Between the $156 and $560 conditions, demand for cocaine was income elastic in about 40 percent of the subjects.

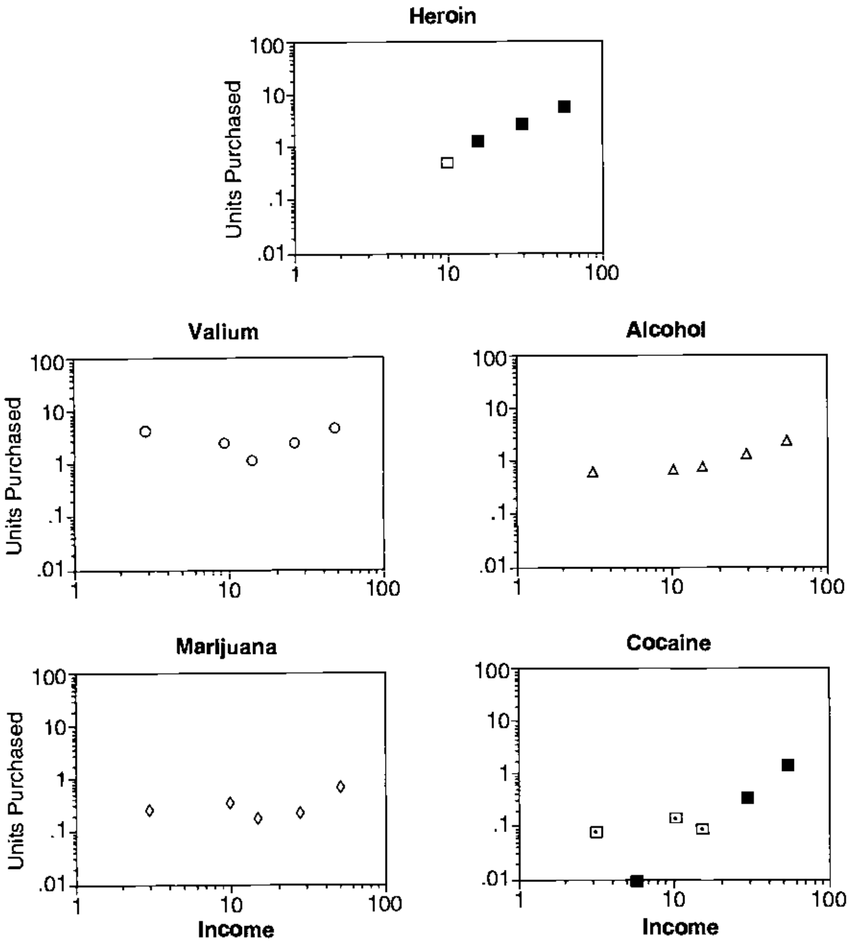

Fig. 8.5 Mean units of heroin, valium, alcohol, marijuana, and cocaine purchased as income increases from $30 to $560

Note: Data are plotted in log-log coordinates such that the slope between any two successive potnts is equal to the E_{inc} values listed in table 8.4. Purchases that differ significantly from the $30 tncome condition (or $100 income condition for heroin only) are denoted by filled symbols. No herotn purchases were made in the $30 income condition since price exceeded tncome, and thercfore no symbol is plotted for heroin in this condition. See text for further details.

Less than 25 percent of the subjects showed income elastic demand for any of the other drugs across the income conditions.

8.3 Summary of Findings

Three major findings emerged from these studies (Petry and Bickel 1998). First, these data show that the price of heroin affects the purchase of some

Table 8.6 **Income Elasticity Coefficients Determined from Mean Units Purchased**

Income ($)	Heroin	Valium	Alcohol	Marijuana	Cocaine
30	—	—	—	—	—
100	—	−0.335	0.075	0.200	0.359
156	1.583	−1.310	0.320	−1.175	−0.757
300	0.912	0.912	0.651	0.231	1.671
560	0.863	0.759	0.680	1.376	1.617
Slope of best-fitting line	1.038	−0.004	0.370	0.152	0.708

other drugs; notably, increases in heroin price resulted in increases in valium and cocaine purchases. Second, as heroin prices increased, own-price elasticities indicated that demand for heroin was relatively inelastic at low prices but elastic at higher prices. Third, as income rose, heroin and cocaine purchases increased, but other drug purchases remained unchanged.

When heroin price rose in experiments 1 and 2, purchase of valium increased. Cross-price elasticity coefficients indicated that valium was a substitute for heroin in most subjects. Cocaine was also a substitute for heroin, but only in a minority of subjects. An independent or weak substitute relationship was found between heroin price and the purchase of marijuana and alcohol.

Experiment 2 demonstrates an asymmetric substitution effect between heroin and valium. While over 50 percent of subjects substituted valium for heroin, *no* subjects substituted heroin for valium. Heroin purchases were independent of valium prices in all subjects across all conditions. Alcohol and marijuana purchases were independent of valium price as well. Together, these results suggest that increases in price for heroin may increase the use of other drugs, notably valium and cocaine, but that increases in the price for valium are unlikely to affect other drug use in this population.

Own-price elasticity coefficients indicated that demand for valium and heroin was relatively inelastic. In experiment 2, subjects defended valium purchases as price increased, and demand for valium was inelastic in over half of the subjects. Similarly, in the first two experiments, heroin purchases defended rises in price such that as heroin price doubled from $3 to $6 per bag, purchases of heroin decreased by less than half. However, as heroin price rose further to $11 and $35 per bag, demand for heroin became elastic, and the near quadrupling in price from $3 to $11 per bag resulted in a greater than fourfold reduction in heroin purchases.

In terms of the relationship between income and drug purchases in the third experiment, subjects consistently purchased more heroin as they had more money to spend. Income elasticity coefficients indicated that demand for heroin was income elastic as income rose from $100 to $156, and heroin purchases rose in greater proportions than incomes. At higher income conditions, demand for heroin was income inelastic, and increases in purchases were not

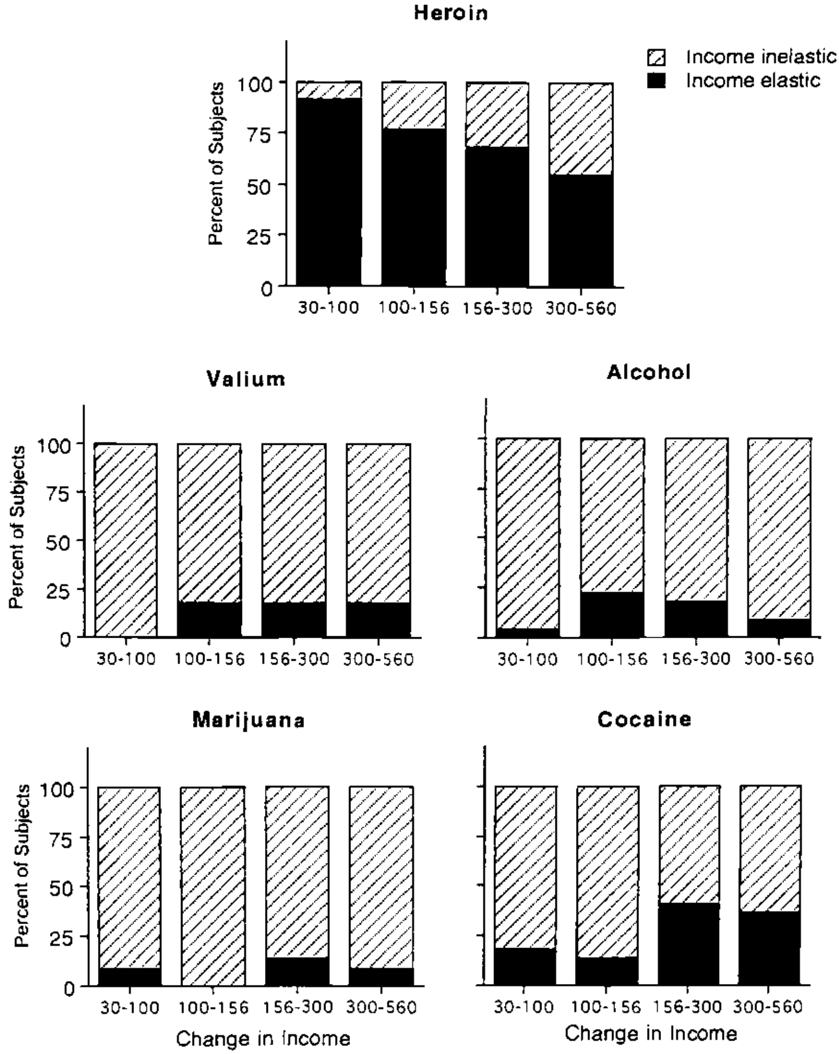

Fig. 8.6 Percentage of subjects demonstrating income elastic or income inelastic demand for heroin, valium, marijuana, alcohol, and cocaine as income rose in experiment 3
Note: See text for further details.

proportionally greater than increases in income. Demand for cocaine was income elastic at high incomes ($156 to $560), and these income levels resulted in significant increases in cocaine purchases compared to the lower income conditions. Purchases of other drugs did not vary significantly with income. In summary, income was most likely to affect purchase of heroin and, to a lesser extent, cocaine; purchases of valium, marijuana, and alcohol were unlikely to change with increasing incomes.

8.4 Reliability and Validity of the Simulation

These data were reliable both between and within subjects. In experiments 1 and 3, each subject was exposed to 9 conditions in a random order. Two of the conditions were identical ($30 income and prices of all drugs at current street value), and 17 of 22 subjects made purchases from the same drug categories in the two exposures to this condition. In experiment 2, 18 new subjects participated. Sixteen conditions were included, and 4 of these ($3, $6, $11, and $35 for heroin and valium at $1 per pill) were virtually identical to a condition in experiment 1, with the exception of cocaine being available only in experiment 1. Own-price elasticity coefficients for heroin were virtually identical in the two groups of subjects (compare tables 8.1 and 8.2).

To assess relationships between self-reports of drug choice in the simulation and actual drug use, we compared drug purchases during the simulation to objective indicators of drug use in real life by these subjects. While in treatment at the clinic, urine samples were collected on a random basis once per week and screened for benzodiazepines, cocaine, marijuana, and opioids using Enzyme Multiplied Immunoassay Technique (Syva Corp., San Jose, Calif.). The percentage of urine samples that tested positive for benzodiazepines and marijuana was significantly correlated ($p < .001$) with the number of valium pills and marijuana purchases made during the simulation. Correlations were conducted between Michigan Alcohol Screening Test scores (MAST, a measure of the severity of alcohol problems; Pokorny, Miller, and Kaplan 1972) and units of alcohol purchased, and those results also approached levels of statistical significance ($p = .09$). While these correlations do not suggest that use of these drugs in real life is related to the demand elasticities of these drugs in this simulation, they do provide preliminary evidence that subjects who "purchase" valium, alcohol, and cocaine in large quantities in the simulation are more likely to use these drugs frequently in real life.

Correlations between opioid-positive urine samples and heroin purchases were not conducted because subjects were required to remain opioid abstinent during treatment. Cocaine purchases were not significantly correlated with the number of cocaine-positive urine samples. One explanation may be that cocaine is more likely to be a complement to heroin than any of the other substances (table 8.1 and fig. 8.2). In natural settings, heroin addicts tend to use cocaine when they are using heroin (speedball). Because subjects were required to remain opioid abstinent during treatment, their cocaine use may have decreased concurrently with their heroin use. Therefore, cocaine urine results during treatment may not have been correlated with the self-reported preference for cocaine during this simulation. Further research with non-treatment-seeking drug users may clarify this issue and further validate this methodology.

Although the data obtained from the simulation were reliable both between and within subjects and urine results tended to corroborate drug selections in the simulation, potential criticisms of the present findings are that all choices were between hypothetical amounts of money and drugs and that all subjects were involved in drug treatment. Whether or not drug abusers actually chose these same amounts and types of drugs in natural settings is unclear. Despite the hypothetical nature of the present simulation, spontaneous verbal reports of subjects during participation in the study suggest that the simulation is related to the real-life experiences of these subjects. For example, one subject reported that each time he receives his paycheck, he thinks back to when he was doing drugs and how he would have allocated such a sum of money to drugs prior to his entering treatment. Many subjects became excited in conditions in which heroin prices were very low or when they received large sums of money with which to buy drugs, and several made statements such as, "It's my lucky day!" Most subjects tried to "bargain" with the experimenter when heroin price exceeded income, and some actually became upset with the experimenter in these conditions. Several subjects tried to "rip off" the experimenter by not "paying" the full amount for the drugs they had verbally requested or by "stealing" the imitation money. The experimenter counted the money after each trial, and confronted some subjects, to ensure that purchases matched income in each trial.

8.5 Relationship between Findings from the Simulation and Drug Use in Natural Settings

One of the main findings of these simulation experiments is that valium is a strong substitute for heroin, and these results are consistent with clinical observations. Benzodiazepines are used to abate opioid withdrawal symptoms during inpatient opioid detoxifications. It is not unreasonable to assume that heroin addicts use more valium when heroin becomes too expensive or is unavailable in natural settings (e.g., Woods, Katz, and Winger 1987) and when heroin addicts are detoxifying as outpatients (e.g., Green and Jaffe 1977; Green et al. 1978).

Only one known study has provided an economic analysis of the substitutability of drugs in natural settings. Chaloupka and Laixuthai (1994) found that drinking frequency and heavy drinking episodes were negatively related to alcohol costs and minimum legal drinking age, but reductions in alcohol use were associated with increases in marijuana use and marijuana-related car accidents. Thus, marijuana tends to be a substitute for alcohol among adolescents.

In terms of own-price elasticity of demand, these data show that demand for heroin is inelastic during small changes in price but that demand becomes more elastic at higher prices. Naturalistic research also demonstrates that demand for heroin is relatively inelastic. For example, pooled cross-sectional time-series data on 41 neighborhoods in Detroit during the 1970s found the own-price elasticity of demand for heroin to be −0.26 (Silverman and Spruill 1977). Van Ours (1995) also found the demand for opium in Indonesia during the Dutch colonial period to be relatively inelastic, with own-price elasticity values ranging from −.70 to −1.0. Nonetheless, the elastic demand for heroin noted at high prices suggests that if prices become high enough, use of heroin may decrease, even among dependent heroin addicts.

This relatively inelastic demand for heroin may have important social implications. If consumption decreases only slowly with increased price, one can expect enhanced drug-seeking behavior associated with small price increments (see also Bickel and DeGrandpre 1996). In other words, original consumption levels may be maintained despite price increases by engaging in criminal activities and trading sex for drugs and money. Silverman and Spruill (1977) and Brown and Silverman (1974) demonstrated that property crimes, as opposed to nonproperty crimes like rape and murder, were positively and significantly affected by heroin price. Additionally, one can hypothesize that the use of more efficient modes of drug taking, such as intravenous injection, may assist in defending consumption levels against price increases.

Participation elasticity (sampling of drugs among nondependent individuals) may also be responsive to drug prices and/or income levels. For example, using data from the National Household Survey of Drug Abuse and the Drug Enforcement Agency, Saffer and Chaloupka (1995) found that participation elasticity is about −.90 to −.80 for heroin and about −.55 to −.36 for cocaine. They estimate that legalization would lead to about a 60 percent decrease in drug prices. These decreases in price are estimated to result in a 100 percent increase in the quantity of heroin consumed and a 50 percent increase in the quantity of cocaine consumed. Decriminalization of marijuana was estimated to increase the probability of marijuana participation by only about 5 percent. The relationship between demand elasticities derived from these statistical estimates and those obtained in simulation paradigms employing nondependent recreational drug users may be of interest.

8.6 Conclusions and Future Applications

In summary, this simulation paradigm appears to be useful for examining the relationship between drug prices and consumption. The data were reliable between and within subjects, consistent with clinical observations of polydrug abuse, and compatible with the limited amount of data relating drug prices to consumption in natural settings. Further examination of the relationships between drug price and consumption using this simulation may elucidate prevention and treatment strategies for drug abuse. In terms of prevention, this procedure may serve as a gauge for at-risk recreational users. Nondependent recreational users may demonstrate lower own-price demand elasticities than dependent users, and individual differences in demand elasticities may be related to risk for dependency and/or response to treatment.

In terms of treatment, drug prices may be strongly associated with entry into treatment. For example, Dupont and Greene (1973) demonstrated that methadone acceptability, as indicated by treatment entry, increases with rises in the retail price of heroin. Similarly, in a series of questionnaires, Vermont heroin addicts were asked to indicate whether they would use heroin, enter into treatment, and withdraw from treatment as the price of heroin varied from $1 per bag to $100 per bag; price was strongly associated with self-reported use and entry to treatment. Interestingly, once in treatment, these patients reported that they were *not* likely to drop out of treatment, although they were more likely to use while in treatment when heroin price was low (Petry and Bickel, unpublished data). Given the strong negative relationship between treatment for drug use and HIV infection (e.g., Metzger et al. 1993), further exploration of the relationship between drug prices and treatment entry is warranted.

Appendix

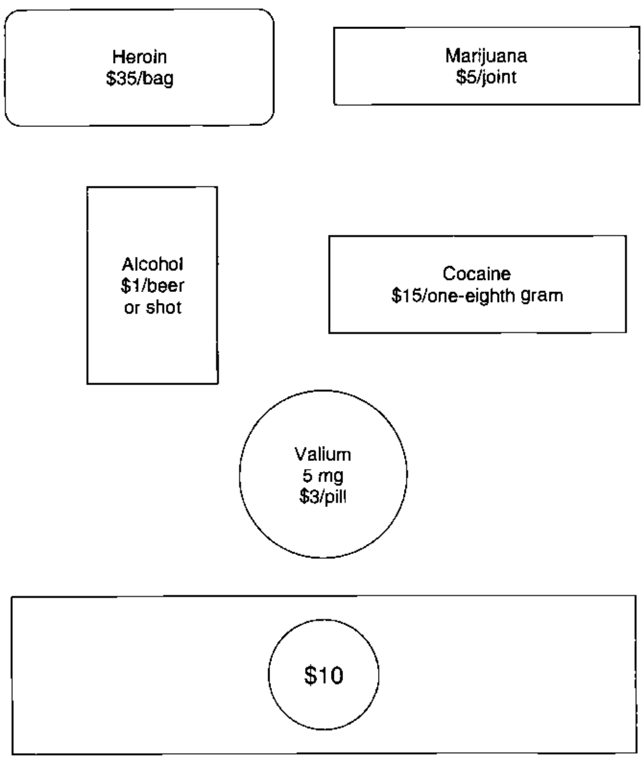

Fig. 8A.1 Sample drug and money stimuli

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Comment on Chapters 7 and 8

A. Thomas McLellan

In reading the Petry and Bickel paper, I was immediately appreciative of Dr. Petry's very clear discussion of the underlying premises and her use of operational definitions for phrases and terms that were very foreign to this clinical researcher. Terms like *elasticity, substitution, complementarity,* and *endogeneity* are as foreign to me as the terms *discriminative stimulus, conditioned inhibitor,* and *selective seratonin reuptake inhibitor* may be to many of the economists. After reading this paper I found myself prompted to use these new economic terms to ask questions that might extend and clarify (at least for me) some of the experiments reported upon in their paper. For example, I wondered to what extent was the elasticity of choice among drug 1 versus drug 2 versus no drug a function of the following variables, which themselves may be elastic:

1. history of use of the substances (dependence, abuse, use)
2. expected effects of a the target amount and type of drug
3. cue-mediated arousal (i.e., advertising effectiveness, potency)
4. current dependent state (joint function of amount of last use, quality/purity of last use, time since last use, and use history)

Armed with these now clarified concepts—that is, all the dangers associated with a little knowledge—I will offer some suggestions on the Petry and Bickel paper as well as some cautionary, general comments on the application of economic analyses with clinical populations. The Petry and Bickel paper is concerned with what appears to be a very common economic concept—the interaction of demands for two or more potentially interchangeable goods, co-occurring within a consumer who has only a fixed amount of money. Here the overall question is, To what extent and under what conditions do economic models and tests of those models pertain in the study of polydrug use? This is a very important and timely issue, since as the authors note, this is common in everyday life and is increasingly common in the treatment setting.

In this context, I was also intrigued by the authors' use of the "imagine if" or "act as though" instruction to study these co-occurring demands. This could serve as an important laboratory model for exploring the elasticity and complementarity issues. In this regard, I think that some calibration might be in order to validate the approach and standardize its use—particularly in the case of drugs with indeterminate potency and purities (e.g., heroin, cocaine, marijuana). For example, in the case of cocaine, to the extent that these background factors are important in explaining the elasticity of demand and complementarity of demand for other drugs, it might be useful to begin each subject with a series of standardized slides (presented in random order and repeated) showing graduated amounts of crack and asking the subject to "indicate the slide that is worth $10, $20, or $30, under conditions where you had the amount and didn't

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require it for immediate needs." This would be the equivalent of standardizing scores on a test and would allow direct comparisons among individuals. A second methodological point that might be useful in validating the use of the paradigm would be to repeat the initial "worth-estimating questions" at later points in the course of the drug comparisons.

Moving from the methodological comments to my comments about the nature of the research, I must say that this paper and this conference have provoked me with some new questions regarding the nature of drug dependence. I should first reiterate that I am a *clinical* researcher working within a *treatment* setting that is part of a *health care system.* I have come to believe that the extreme (epidemiologically and socially) behaviors that are the subject of this conference—like heroin and cocaine dependence—are "diseases," and that among the more appropriate and efficient means of dealing with them is through the application of more or less standard treatment interventions within a health care setting—paid for with health insurance. Therefore, within this conference, the premise that has been most interesting to me was stated early by Dr. Henry Saffer: that demand, price, and income parameters affect the consumption of alcohol, cocaine, and opiates under "the same theoretical demand model that is used for other goods" (section 7.3.1). It is important to note that from a treatment perspective, use of all of these drugs has not been conceptualized as being on a smooth continuum of amount, duration, and frequency, but rather on a *discontinuum,* with important breaks at various points. Use, use-to-intoxication, problematic use, and even abuse are (depending upon the operational definitions and measures used) on some type of continuum based on amount, frequency, duration, and *consequences* of use. However, dependence in the psychiatric diagnostic sense is specifically defined as use that is "out of control," "continued despite clear negative consequences," "use that is out of volitional control," and "not rational"; this is why it is called addiction—to set it apart as a disease state, separate from other so-called rational behaviors.

Thus, as a clinical researcher, I was immediately confronted by an assumption that runs contrary to the foundation of why dependence is considered a medical disorder and why it needs treatment instead of simple exogenous behavioral controls such as might be supplied by the criminal justice system or the laws and economic conditions of an economy or government. I think this may be important for both of our disciplines to study. It strikes me that if the laws of rational economics apply reasonably well to the exchange of money, effort, or other barterable commodities for drugs—under conditions where the individual meets contemporary criteria for a substance dependence disorder—such a finding will cast doubt on one of the fundamental assumptions underlying medially oriented treatments for substance dependence. In turn, such a finding might help us all to consider new forms of interventions designed to capitalize on the rational choices that are being made by "addicted" individuals. If this line of research fails to confirm the expected operation of these fundamental principles of economics when applied to drug exchange among addicted individuals, it could provide some important considerations on the operation of exchange principles under "irrational" demand conditions.

My final comments focus on the overall nature of the work that has been presented over these past two days—again, from the perspective of a clinical researcher. In this regard, I will conclude with three general requests of the economic researchers—based on the data presented at this conference:

Please continue to study these issues. It is apparent that economic principles, assumptions, and analytic methods may be important tools in the study of prevention and treatment of use, abuse, and dependence.

Please study populations that are dependent (in the psychiatric diagnostic sense) as well as large general populations. However, I urge caution in the implications drawn and even the titles of articles. Please don't use the words *abuse* and *dependence* in titles of articles unless those definitions are clarified. As indicated above, these words have multiple meanings to workers in these fields. Please be careful in generalizing to clinical populations and to behaviors that may fall under additional—possibly qualitatively different—mechanisms.

I say this because, often, economists and economic findings are used by policy makers. It may be that some of the governmental policies that derive from economic findings will apply nicely to those who have not yet used (prevention) or those who are using at relatively low rates or amounts (users). But it is at least possible that these same findings may have inaccurate implications for those whose use is highest (those with histories of dependence and/or those with current dependence).

Get better data than have been presented here. The only area that has disappointed me in this conference has been the nature of some of the data sets that have been used for study and, I believe, a too rapid rush to generalize to clinical populations. There is the understandable desire to work with large databases that are publicly available. Many of the studies presented have used these databases, I think without sufficient caution and critique. Too often, these data sets were used in an attempt to study rather extreme or rare behaviors such as alcohol abuse or dependence. The databases used in several of these studies had very few of these extreme cases, and often the nature, number, and precision of the variables used to characterize these populations were inadequate for a true test of some of the assumptions underlying the analyses. Too often, a poorly defined variable was constructed to be used as a proxy for an important construct—such as "abuse" or "dependence"—but without empirical or even casual testing of the extent to which the proxy actually represented the construct under study.

My plea to the economic researchers is this: Don't settle for this level of data when there are far better and more informative data sets available. There are many randomized clinical trials that include large samples of carefully measured patient populations (i.e., abusing and dependent patients) available for study. There are population-based data sets that use the same measures as clinical samples. There are state-level data on treated populations with varying levels of treatment intensities, services, and controls on admission and treatment length. There are field studies with fine-grained measures of important behaviors that are socially relevant.

I am a council member of the National Institute on Drug Abuse and a member of the Health Services Advisory Board for the National Institute on Alcohol Abuse and Alcoholism. In that capacity, I can say that there is great interest in the economic study of these data sets and populations from both of these agencies. As a clinical researcher, I have been impressed with the power of the economic methods employed in the studies presented here. My only caution is that these methods should be explicitly tested in clinical populations prior to assuming that the findings will generalize to those populations.

Comment on Chapters 7 and 8

Mark A. R. Kleiman

Addiction, Rationality, Behavior, and Measurement: Some Comments on the Problems of Integrating Econometric and Behavioral Economic Research

The general problem addressed by this conference is: What do econometrics and behavioral economics have to say to one another, and to the broader world of thought and policy making, about the phenomena of drug abuse? Asking this question plunges us into deep and murky waters, both methodologically and conceptually.

To start with some of the methodological problems:

Econometricians are the prisoners of their data sets. The data about drug abuse are lamentably, and notoriously, poor. Even such a pedestrian and important variable as the potency-adjusted price of cannabis (which might be thought of as the price of a gram of THC, the primary active agent) is simply unknown, since seized cannabis is not systematically assayed. The picture is somewhat better for heroin and cocaine, which are routinely assayed for purity, but even there the quality of the price data is nothing to write home about.

Even if money price were well measured, the other components of what Mark Moore (1973) has called "effective price"—perceived risk of taking the drug, perceived risk of acquiring the drug, and search time—would remain almost entirely unmeasured.

With respect to consumption, econometric analysis perforce relies primar-

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ily on survey data from such sources as the National Household Survey on Drug Abuse (NHSDA) and the National Longitudinal Survey of Youth. These samples are drawn from the general population, and the sampling procedures are weighted against the subpopulation of drug users, and even more against the smaller subpopulation of frequent, high-dose users. (Heavy users are more likely than average to live at hard-to-sample locations, and less likely than average to want to talk with government-sponsored interviewers.) As a result, the NHSDA misses about three-quarters of the heavy cocaine users.

Since all drugs, except for cigarettes, have highly skewed consumption distributions that more or less follow Pareto's 80/20 law (four-fifths of the consumption accounted for by one-fifth of the users), missing the heavy users badly distorts the overall consumption picture. Projecting NHSDA answers about the frequency of cocaine consumption onto the national population generates an estimated total volume of about 30 metric tons per year, or about one-tenth of the estimated true volume of about 300 tons per year.

Thus, the light users, whose overall contribution to consumption is negligible and whose behavior patterns are quite different from the behavior patterns of heavy users, dominate the data sets and therefore the analyses. The samples of very heavy users are too small (and too atypical of heavy users generally) to permit mere reweighting to solve the problem: Though it appears that three-quarters of heavy cocaine users are arrested in the course of any given year, only one-tenth of the NHSDA self-reported heavy users report ever having been arrested.

As for behavioral economics, the chief issue as I see it is how to relate its findings to the actual phenomena and to the concepts of pure microeconomics. In particular, the concept of the price elasticity of demand needs to be handled very carefully.

The textbook definition of elasticity holds income constant. In studying the consumption of goods that make up small portions of consumers' budgets, this is of little importance; the price of razor blades does not measurably influence the labor supply of those who shave. But heavy users of expensive illicit drugs spend very large portions of their total budgets on the drugs they buy, and it seems reasonable to speculate that one effect of higher prices might be increased efforts to secure income, including by theft. This is sometimes referred to as evidence of inelastic demand, but as David Boyum has pointed out, a heroin addict who keeps his consumption constant as price rises by committing more burglaries is not showing inelastic demand in the textbook sense. Behavioral economics may have a great deal to teach us about the impacts of drug prices on the markets for licit and illicit labor, but this needs to be distinguished from the measurement of price elasticity.

Similarly, empirical drug abusers do spend money on things other than drugs, and could greatly increase their disposable income for nondrug purchases by cutting back somewhat on their drug purchases. This limits the relevance of findings from experiments in which only drugs are available for hypothetical purchase or as behavioral reinforcers.

Now to what I see as the major conceptual issue: the concept of "rational addiction." This phrase can be used in (at least) three distinct senses, for which I have attempted to supply descriptive labels:

"Minimal rationality." This means only that the law of demand applies to drug taking, and that drug taking is controlled in part by its contingencies, even for those who are addicted—those who have impaired volition or an impoverished choice set or both due to prior drug taking, and whose current drug taking is perceived by themselves and others as problematic.

There is much loose talk around, in both medical and policy circles, about the disease model of addiction, suggesting that the discovery that for some people drug taking is a pathological behavior somehow means that addicts do not respond to prices or contingencies. If that's all the "rational" in "rational addiction" means, then it represents a much-needed corrective to such loose talk, and there is no reason to object to it.

"Foresight only." This means that consumers of addictive drugs are capable of forecasting future prices and, in particular, the impact on their own future budgets of their own (predictable) habit formation. Thus, current consumption will be sensitive to predicted changes in long-run prices. But taking such drugs can still reduce overall expected utility, in particular by increasing rates of time preference.

"Global maximization." This means that the use of addictive drugs reflects the rational pursuit of maximum (expected) utility. Initiation, persistance, desistance, and return to use are all choices made with perfect foresight and self-command. This seems to imply that addictive drugs produce consumers' surpluses for their addicted users.

Global maximization as a description of addictive behavior has a strong implication: that drug addiction is not a social problem—or would not be a problem in the absence of prohibition—except for its external costs. If all of the consumers are enjoying surpluses—at least expected surpluses as evaluated ex ante—then we should erect policies such as Pigouvian taxation to correct the externality problem and then go home. (Drug addiction might reduce total utility by increasing discount rates, but that effect should also be rationally taken into account by a perfectly rational consumer.)

Such a model would be consistent with the existence of a class of unhappy addicts expressing regret about their initial decision to start taking drugs; they would simply be the unlucky ones for whom the risk of addiction became a reality. Their net losses would, still assuming rationality, have to be less than the net gains of those who managed to use without becoming addicted, plus a premium for risk.

But that model would make very strong predictions about the behavior of users, addicted and nonaddicted alike:

1. They would seek to buy at the minimum (expected, discounted) price.
2. They would apply the same discount rate to drugs and other goods.
3. They would discount geometrically, with no preference reversals.

4. As expected-utility maximizers, they would be risk averse (given diminishing marginal utility for income), again for drugs and other goods alike.

5. No drug user would ever do anything that he or she expected later to regret; that is, self-command would not be a problem.

6. In the absence of self-command problems, there would be no self-strategy; that is, no costly attempts to prevent, or mitigate, anticipated irrational behavior.

Now these predictions, it seems to me, are clearly falsified by observations of actual and laboratory behavior. To give only four examples:

1. Heroin addicts, who spend large proportions of their total income on the drug, do not take advantage of the very large discounts—in addition to reduced transactions costs—available from buying several days' supply in bulk. They report that this is because they know themselves to be incapable of not using the entire purchase at one sitting. (Since I behave the same way about candy, I do not find such reports implausible.)

2. Laboratory-measured rates of time preference are higher for heroin than for other reinforcers.

3. People who have gone through a period of addictive use, and then stopped, report fearing that they will return to addictive use.

4. Contingency management works as a drug treatment modality even when the sums involved are negligible compared to the cost of maintaining a drug habit.

This is not, I submit, puzzling, except from the viewpoint that views all behavior as necessarily maximizing. Melioration, hyperbolic discounting, and prospect theory all provide models of consistent, but not globally maximizing, behavior, and all have something to contribute to understanding the phenomena of drug abuse (Heyman 1996).

Full rationality is an idealized abstraction of some aspects of behavior, and it should not surprise us that actual behavior conforms to its normative precepts only imperfectly. The extent of those imperfections will vary with the individual, the topic of decision, and the circumstances. I would propose that we understand an addictive drug (or other behavior, such as gambling) as one that is unusually susceptible to some subset of behavioral deviations from full rationality. That will make addictive drugs and other activities different—in degree rather than in kind, but in important degree—from the activities for which full rationality provides a workably good description of actual behavior.

This third, global interpretation of rational addiction, with which I approached reading the papers in this volume, is, I believe, the way that theory is generally understood by those outside the circle of rational addiction researchers. That will excuse my devoting so much space to tearing down what I am now told is a straw man: The correct interpretation is said to be what I call above "foresight only." Drug consumers, including addicts, are foresighted rather than myopic when it comes to prices, but excessive drug taking both reflects and intensifies inappropriately high rates of time preference, thus reducing consumers' utility. That leaves open the question of why addicts' rationality is impaired in such a specific way. It also, I believe, leaves unexplained the phenomena of preference reversal, inconsistent discount rates across goods, and self-strategizing.

Abandoning my (never very successful) attempt to impersonate a social scientist, I now resume my true identity as a policy analyst and ask, What findings from econometrics and behavioral economics would be of most use in facilitating better public policies?

First and foremost, we need better knowledge of the effects of price on consumption and other behavior (and, ideally, of the effects of enforcement effort on price).

Here, aggregates are of limited use. As with many commodities, the relevant elasticities will vary not only across drugs but across user subtypes and probably over time. (In addition, as Boyum [1992] has suggested, elasticities for upward and downward price movements may not be symmetric, and overall consumption patterns may display hysteresis.) Since the welfare implications of changes in consumption levels depend crucially on whose consumption is changing, the overall point elasticity is of only modest help in shaping policy. Ideally we could use a full set of own- and cross-price elasticity functions, broken down into effects on initiation, persistance/desistance, intensification, quit, and relapse.

The possibility that two drugs could be substitutes contemporaneously but complements over time (which could be the case if two drugs both satisfied the same underlying demand for intoxication, but that demand was an increasing function of past intoxication) needs to be taken seriously, and might be profitably explored using laboratory animals.

The possibility that changing drug prices could change the licit and illicit labor supply of some users needs to be explored empirically, recognizing that this is not the same as the elasticity question.

Almost nothing quantitative is known about the effects on consumption of nonprice variables, including search time. To be productive, this work will probably require recruiting user panels.

As Peter Reuter (1997) has pointed out, about three-quarters of the current efforts to reduce illicit drug use consist of enforcement, aimed presumably at increasing prices and search times. But next to nothing is known about how the magnitude or design of such efforts influences these intermediate variables, or about how the intermediates change drug consumption or other variables of social interest such as crime. (As Reuter has also pointed out, the research budget is even more strongly skewed toward basic biology and the study of drug treatment than the operating budget is toward enforcement.) To study enforcement econometrically, it will be necessary to design and implement much more disaggregated and precise models and measures of enforcement efforts and outputs.

The overall contribution of economic analysis to making drug policy is, of course, limited in part by the politics of drug abuse control and by some agencies' limited appetite for analysis, especially analysis likely to disrupt current patterns of practice. In fairness, however, it must be said that those constraints are not, for the most part, currently binding, since our knowledge is not now either robust enough or precise enough to allow much in the way of policy advice. Perhaps when we know better what to do there will be greater willingness than is now apparent to make use of that knowledge.

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