ENVIRONMENTAL FACTORS

Economics of youth drug use, addiction and gateway effects

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Abstract

The use of illicit drugs by American youth rose dramatically during the 1990s. Reducing these trends is an important policy objective. However, for policies to be effective it is important to understand the key causal links that lead to substance use and abuse. Policy makers must understand whether attempts to reduce the demand for one drug have impacts on the current and future use of other drugs. This paper overviews an economic approach to modeling drug use, addiction and gateway effects, emphasizing the potential of this method for identifying causal links in consumption. The paper demonstrates how this multi-substance theory of drug use leads to empirical specifications that can identify the impact of consumption of one drug on the contemporaneous and future consumption of other drugs. This is followed by a discussion of what types of data would be needed to estimate these effects.

1. Introduction

Society devotes substantial resources to the prevention of drug use and addiction, the enforcement of drug laws and the treatment of drug abuse and drug abuse-related health problems (Rice et al., 1990; Harwood, Fountain & Livermore, 1999). Even those who advocate decriminalization or some form of legalization for adult use of marijuana and other drugs recognize adolescent drug use as unacceptable (Krauss & Lazear, 1991). The national health promotion objectives set forth in Healthy People 2000 call for substantial decreases in adolescent drug use (Public Health Service, 1990). In this light, the upward trends in drug use among high school students during the 1990s is particularly disturbing. Although recent data suggest a modest 1-year decline for some drugs, use of any illicit drug during the 1990s rose from a low of 27.1% in 1992 to a high of 42.4% in 1997 (Johnston, O’Malley & Bachman, 1998). Reducing these trends is an important policy objective. However, for policies to be effective it is important to understand the key causal links that lead to substance abuse. Most importantly, policy makers must understand whether attempts to reduce the demand for one drug will change the current and future demand for other drugs. On one hand, users might substitute a new drug for the drug that policy makers are attempting to reduce. On the other hand, reducing the use of a gateway drug might reduce the...
future use of this and other drugs. Epidemiological studies reveal a sequence of use of different substances, where adolescent use of substances that are legal for adults, i.e. cigarettes and alcohol, are identifiable risk factors for subsequent use of illicit drugs. The epidemiological evidence does not determine whether the sequence of drug use can be attributed to a casual link in the demand from one drug to another, or arises from unobserved differences in preferences, environments, access, or other factors (i.e. heterogeneity). This distinction is extremely important for policy. For example, if use of tobacco is causally linked to subsequent marijuana use, policies that limit the use of tobacco will eventually affect marijuana demand. If, however, the sequence results from unobserved factors, policies targeting tobacco are not likely to affect the onset of other drug use.

This paper overviews an economic approach to modeling drug use, addiction and gateway effects, emphasizing the potential of this method for identifying causal links in consumption. The first section of the paper sets the stage by providing some descriptive data on the use of a variety of drugs among American high school students and discusses some of the implications of these trends. The second section provides a very brief review of the economics of drug use literature. The third section of the paper presents an economic model of multi-substance drug use. The next section outlines how this theory leads to empirical specifications that can be used to identify the impact of consumption of one drug on the contemporaneous and future use of other drugs. The final section discusses the types of data that would be needed to implement this specification.

2. Background
2.1 Trends in high school students’ drug use
Recent discouraging trends in high school students’ drug use have attracted a great deal of publicity. Evidence from several different national data collection efforts point to the same conclusion: after more than a decade of steady decline, in the early 1990s adolescent drug use began to sharply increase. Figures 1 and 2 presents illustrative estimates from the Monitoring the Future (MTF) study. The MTF study has surveyed large nationally representative samples of high school seniors each year since 1975; in 1991 annual surveys of 8th and 10th graders were added. The MTF provides estimates of life-time use, annual use, 30-day use and daily use of various illicit drugs, alcohol and tobacco.

Figures 1 and 2 show the trends of 30-day use of marijuana and cocaine for 1988–98. These trends are compared to the 1988 baseline estimate of adolescent drug use and the year 2000 objective set forth in Healthy People 2000 (Public Health Service, 1990). Current trends make it extremely unlikely that the United States will meet the Healthy People 2000 objectives for re-
ducing adolescent drug use. Instead of cutting the prevalence of 30-day use of marijuana and cocaine in half, it seems likely that by 2000 use will be more than double the baseline levels. Data from various years of the National Household Survey of Drug Abuse (NHSDA) and the National Parents’ Resource Institute for Drug Education (PRIDE) annual surveys, two other national surveys that obtain estimates of adolescent substance use, show the same patterns as the MTF data. For example, from the NHSDA it is estimated that in 1995 monthly use of marijuana among youth was 8.2%, more than double the 1992 level. Using the PRIDE data, monthly use of any illicit drug by 6–12th graders in 1995–96 is estimated to be 18.3%, up from 10.6% in 1987–88, the first year of the PRIDE survey (National Parents’ Resource Institute for Drug Education Inc., 1996).

The rising trends in adolescent substance use are disturbing because of the potential harmful consequences. Some consequences are immediate. For example, alcohol-related traffic crashes are a leading cause of mortality for youth and young adults. Marijuana has also been associated with non-fatal traffic crashes (Chaloupka & Laixuthai, 1997) and visits to hospital emergency rooms in the Drug Abuse Warning Network (DAWN) data (Model, 1993). There are also long-term health consequences from smoking, drinking and substance abuse, such as addiction, cancer, liver cirrhosis and loss of memory function (Public Health Service, 1990). Other possible long-term consequences include lower educational attainment (Yamada, Kendix & Yamada, 1996) and poor labor market outcomes (Kaestner, 1991; Mullahy & Sindelar, 1993; Kenkel & Riber, 1994) although these have been more difficult to study. The reason why these long-term outcomes are particularly difficult to study is that few publicly available national data sets contain information on drug use over time. One notable exception is the National Educational Longitudinal Survey of 1988 (NELS:88).

The NELS:88 is a large-scale, longitudinal study of approximately 24,500 American 8th graders in 1988 as they move through the US school system and into the many and varied activities of early adulthood. Follow-ups of the respondents were conducted in the spring of 1990, when most were sophomores in high school, and then in 1992, when most were high school seniors. The first follow-up includes responses from roughly 22,500 students, while the second follow-up includes approximately 21,000 students who completed questionnaires. Students who leave high school prior to graduation continue to be interviewed. In addition to information on individual and school characteristics, information is obtained on multi-substance use over time. It is therefore possible to use these data to explore the contemporaneous and intertemporal relationships between particular substances.

Table 1 shows at least three important longitudinal patterns in heavy drinking [heavy or binge drinking is defined as having five or more
Table 1. Use of substances in 10th and 12th grade (un-weighted means)

<table>
<thead>
<tr>
<th></th>
<th>Drinking behavior in 10th grade</th>
<th>Smoking behavior in 10th grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy drinker (N = 3860)</td>
<td>Not a heavy drinker (N = 13355)</td>
</tr>
<tr>
<td>Heavy drinking in 12th grade</td>
<td>0.605</td>
<td>0.247</td>
</tr>
<tr>
<td>Heavy smoking in 12th grade</td>
<td>0.183</td>
<td>0.099</td>
</tr>
<tr>
<td>Marijuana use in 12th grade</td>
<td>0.092</td>
<td>0.020</td>
</tr>
<tr>
<td>Cocaine use in 12th grade</td>
<td>0.052</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>Heavy smoker (N = 1600)</td>
<td>Not a heavy smoker (N = 15627)</td>
</tr>
<tr>
<td></td>
<td>0.437</td>
<td>0.316</td>
</tr>
<tr>
<td></td>
<td>0.378</td>
<td>0.092</td>
</tr>
<tr>
<td></td>
<td>0.086</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>0.046</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Source: NELS:88. The number of observations for each cell differs based on whether there was missing data for the relevant variable. Tabulations performed by the authors.

consecutive drinks at least once in the last 2 weeks], heavy cigarette use [heavy smoking is defined as smoking more than half a pack a day], heavy marijuana use [heavy marijuana use is defined as having used marijuana more than 20 times in the last year] and cocaine use [cocaine use is defined as using within the last year]. Although we focus on the patterns for heavy users, similar patterns exist for other types of use.

First, youths in this sample experience large increases in the propensity to engage in substance use/abuse between 10th and 12th grades. For example, almost 25% (24.7) of non-heavy drinkers in the 10th grade report being heavy drinkers in the 12th grade. Similarly, 32% (31.6) of non-heavy smokers in the 10th grade report being a heavy smoker by the 12th grade.

Secondly, there is a strong positive correlation between use of a substance in 10th grade and future use of the same substance. While this, of course, does not establish addiction, it is consistent with the theory that early use leads to continued heavy use of substances. Of those that are heavy drinkers in 10th grade, 61% continue to be heavy drinkers in 12th grade. Of those that are heavy smokers in 10th grade, 38% continue to be heavy smokers in 12th grade.

Thirdly, there is a large positive correlation between heavy use of alcohol and cigarettes in the 10th grade and future use of other substances. Those who are heavy drinkers in the 10th grade are much more likely than non-heavy drinkers to report using marijuana and cocaine in 12th grade. Similarly, those that were heavy smokers in the 10th grade are much more likely to report being marijuana and cocaine users in the 12th grade than those who were not heavy smokers. It is this pattern in consumption over time that has led some researchers to conclude that alcohol and cigarettes operate as gateway drugs.

3. The economics of substance use and gateway effects

Economists bring unique and useful perspectives to the understanding of substance use formation and abuse prevention. Other social scientists see adolescent decisions about smoking, drinking and drug use as examples of problem behavior in the general context of psychosocial development (e.g. Donovan, Jessor & Costa, 1988; Jessor, 1991; Lowry et al., 1994). The economic approach emphasizes that smoking, drinking and drug use can also be seen in the context of individual consumer decision-making. This leads economists to focus on prevention policy tools that impact the demand for these substances (such as taxation) and the supply of these substances (restrictions on availability). By bringing new perspectives and methodological tools we feel the economic approach complements other research approaches to understanding adolescent substance abuse and prevention policy.
3.1 Single-substance studies

Studies using the economic approach have made important contributions to tobacco and alcohol abuse prevention policy. Most of these studies estimate the demand for various substances separately. These empirical studies provide evidence that consumers’ decisions about tobacco and alcohol are consistent with the economic “law of demand”: when the prices of these substances go up, the amounts consumed fall. Differences in tobacco and alcohol prices over time and across states have supplied, in effect, a series of “natural experiments” on the price–consumption relationships. Econometric methods are used to control statistically for other influences on demand, such as income, environment and demographic factors. Tobacco and alcohol demand functions have been estimated using different types of data and measures of consumption: time-series data on national aggregate consumption; pooled time series of state cross-sections; and micro-level data on consumption from surveys of individuals. The degree to which consumption is affected by price can be summarized by the price elasticity of demand, which is defined as the percentage change in the quantity demanded that results from a 1% change in price. As reviewed by Chaloupka & Warner (2000), estimates of the price-elasticity of demand for cigarettes vary from $-0.14$ to $-1.23$, although most fall in the narrower range of $-0.3$ to $-0.5$. Estimates of the price-elasticity of alcoholic beverages, as reviewed by Manning et al. (1991, Appendix A) range from $-0.5$ to $-1.6$ [1]. These estimates provide the basis for a strong consensus that the price elasticities of both tobacco and alcohol demand are negative and large enough that price increases will cause substantial decreases in consumption.

Because taxes can be manipulated they are potential tools to promote public health (Grossman et al., 1994, Kenkel & Manning, 1996). For example, the 1988 25-cent state tax increase in California alone is estimated to have reduced sales of cigarettes by 819 million packs (Hu, Sung & Keeler, 1995). A recent study by Moore (1996) addresses the public health consequences of tobacco taxation more directly by estimating the relationship between mortality rates and tobacco excise taxes. Based on the results, a 10% increase in the tobacco tax is projected to save over 6000 lives a year. Similarly, considering only deaths due to drunk driving, Chaloupka, Safer & Grossman (1993) estimate that doubling the beer tax would have reduced traffic fatalities per year by 1744.

From the outset, economists have encountered some skepticism about the role of prices or taxes as determinants of tobacco and alcohol demand because of the addictive nature of these goods. The standard economic model of consumer demand can be extended to incorporate habit-formation (Houthakker & Taylor, 1970) and addiction (Becker & Murphy, 1988). Consumer demand for an addictive good is still predicted to fall when prices increase, with a greater response to a permanent price increase in the long term than in the short term (Becker, Grossman & Murphy, 1991). Empirical studies of cigarette demand using the Becker-Murphy framework find significant negative price elasticities, and consistent with the model’s predictions find that the long-term price response exceeds the short-term response (Chaloupka, 1991; Keeler et al., 1993; Becker et al., 1994). Grossman (1993) reviews this approach in more detail and discusses its potential as applied to alcohol demand. Recent alcohol demand studies that incorporate addiction provide more evidence that alcohol consumption falls when prices rise (Waters & Sloan 1995; Grossman et al., 1998). This is consistent with earlier studies that find strong relationships between alcohol prices or taxes and various measures of alcohol abuse, including liver cirrhosis death rates, motor vehicle fatality rates and workplace accidents (Cook & Tauchen, 1982; Chaloupka, 1993). Manning, Blumberg & Moulton (1995) develop an econometric approach to provide a more complete picture of the degree of price responsiveness for various subgroups of drinkers. Both Manning et al. (1995) and Kenkel (1996) find that many heavy drinkers are responsive to price, but there is evidence of a subset of very heavy drinkers who are not.

Estimates of the effects of higher cigarette taxes or prices on youth smoking have attracted a great deal of attention during the public debate on the proposed national tobacco settlement. Several studies published in the early 1980s lend empirical support to the notion that youth smoking is more price sensitive than adult smoking (Lewit et al., 1981; Lewit & Coate, 1982). As noted by the Institute of Medicine (1994) and a leading health economics textbook (Folland et al., 1997), the early consensus later began to
crumble [2]. Three subsequent studies found statistically insignificant effects (Wasserman et al., 1991; Chaloupka, 1991; Douglas & Harrihan, 1994). Published and unpublished studies since have generated conflicting results, with several studies finding a significant result (Chaloupka & Grossman, 1996 [3]; Chaloupka & Wechsler, 1997; Evans & Farrelly, 1998) while others find no effect (Douglas, 1998; DeCicca, Kenkel & Mathios, 1999). Some of the conflict can be explained by differences in empirical approaches as well as gender and race differences that become hidden with different pooled samples [4].

Economic demand studies also consider the role of other determinants of youth smoking and drinking decisions, including policy-manipulable variables such as restrictions on availability. By making purchases more difficult or even illegal, restrictions on availability increase the full cost of cigarettes and alcohol. A negative demand response to these restrictions is thus predicted as another example of the law of demand. There is little existing evidence that restrictions on cigarette sales to minors reduces their smoking demand. For example, Chaloupka & Grossman (1996) estimate that the restrictions have little impact, probably because of the weak enforcement of such laws. However, their results suggest that restrictions on smoking in public places and limits on smoking in schools would reduce youth cigarette demand. Chaloupka & Pacula (2000) find that although smoking by white youths is sensitive to clean outdoor air restrictions, smoking by black youths is not. Instead, black smokers are more sensitive to change in youth access laws and smoker protection law which do not appear to influence smoking by white youths. Econometric studies also contribute to the body of evidence that raising the minimum legal drinking age decreases drinking and drunk driving by young adults (Saffer & Grossman, 1987; Kenke, 1993). More recently, using data from the 1993 Harvard College Alcohol Study, Chaloupka & Wechsler (1996) found evidence that restrictions on availability and strong drunk driving policies reduce binge drinking by college students. They also found that other aspects of campus life, including participating in a fraternity/sorority, are among the most important determinants of drinking and binge drinking in this age group. This is a good example of how insights from other social science perspectives can be integrated and tested in the economic demand framework.

The economic approach has been used to study illicit drug use, but this has been more difficult because good measures of the prices of illegal substances are difficult to obtain. To overcome this, Saffer & Chaloupka (1996) merge newly available data on drug prices from the Drug Enforcement Agency’s STRIDE dataset with data on individual data use from the NHSDA. They find that heroin and cocaine use increase when drug prices are low, and that marijuana use increases when it is decriminalized. Similarly, using STRIDE data merged with panel data from the MTF, Grossman & Chaloupka (1998) estimate that the long-term price elasticity of the demand for cocaine is −1.18. Using a different type of data from the Drug Abuse Warning Network, Model (1993) finds that marijuana decriminalization increased use as measured by hospital emergency room episodes related to marijuana. In contrast, several studies that estimate individual-level demand equations using data from the late 1970s and early 1980s find that marijuana use and marijuana decriminalization are not related (Johnston, Bachman & O’Malley, 1981; Thies & Register, 1993). The somewhat disparate findings in previous research point to the need for further economic analyses of illicit drug demand.

3.2 Analysis of contemporaneous demand relationships between several substances

In the standard model of consumer demand different substances can be classified as contemporaneous substitutes, complements or unrelated goods. Two goods are substitutes if an increase in the price of one leads to an increase in consumption of the other. They are complements if an increase in the price of one leads to a decrease in consumption of the other. Existing evidence is somewhat mixed on the nature of the demand relationships between illicit drugs and alcohol, although there is a growing consensus for contemporaneous complementarity. Earlier studies suggest that alcohol and marijuana are economic substitutes. Using micro-level data from the MTF, Chaloupka & Laixuthai (1994) estimate that alcohol demand is lower in states that decriminalized marijuana. Thies & Register (1993) find that marijuana decriminalization has
a negative and significant effect on alcohol and cocaine use but surprisingly no effect on marijuana demand. In contrast, Pacula (1998a, 1998b) finds that alcohol and marijuana are economic complements; that is, goods that are used together so that when the price of one goes up the consumption of both falls. In both studies Pacula uses data from the National Longitudinal Survey of Youth (NLSY). In the first, Pacula (1998a) finds that increases in the beer tax or the legal drinking age decrease the demand for marijuana by at least as much (in percentage terms) as they decrease alcohol consumption. As in Chaloupka & Laixuthai (1997), Pacula also finds that decriminalization decreases the demand for alcohol. At the same time, however, she finds that decriminalization decreases the demand for marijuana. While this result is counter-intuitive, it also raises doubts that the negative effect of decriminalization on alcohol demand can be interpreted as a substitution effect in her sample. Saffer & Chaloupka (1999) find general evidence of complementarity between alcohol, marijuana, cocaine and heroin in a youth subsample of data from the 1988, 1990 and 1991 NHSDA. Finally, Farrelly et al. (1999) also find evidence of complementarity between alcohol and marijuana using data from the 1990–96 NHSDA in a cross-sectional time-series model that controlled for unobserved time-invariant state-specific effects.

Two recent studies examine the relationship between the demands for cigarettes and marijuana among youth. Chaloupka et al. (1999) use data from the 1992–94 Monitoring the Future Surveys of 8th, 10th and 12th graders to estimate individual level demand equations for cigarettes and marijuana. They find that higher cigarette prices are associated with lower levels of marijuana use, again suggesting a complementary relationship between cigarettes and marijuana. This finding is reaffirmed in a separate study by Farrelly et al. (1999), who use data on 12–17-year-olds from the 1990–96 NHSDA. Their models further control for time invariant state-fixed effects that may be associated with cigarette tax rates across states.

3.3 Analysis of inter-temporal demand relationships (gateway effects)
Epidemiological studies provide important evidence of a developmental pattern of drug use, where adolescent use of substances that are legal for adults, i.e. cigarettes and alcohol, tends to precede use of illicit drugs, and use of marijuana tends to precede use of other illicit drugs (for example, see Kandel, 1975; Yamaguchi & Kandel, 1984; Kandel & Yamaguchi, 1993). In this way, the legal substances may be a “gateway” leading to illicit drug use, and among illicit drugs marijuana may be another gateway. As Kandel & Yamaguchi (1993) conclude: “The regularity of the observed sequences at different historical periods, in different populations and in different cultures is striking.” This raises the intriguing possibility that prevention efforts aimed at smoking and alcohol abuse may also pay off in the form of reduced illicit drug use.

Two recent studies have examined the inter-temporal relationship between the demands for different substances, both assuming myopic behavior. Pacula (1998b) considers the relationship between alcohol and marijuana demand at different time-points using the 1983 and 1984 waves of the NLSY. Pacula’s approach is to examine the influence of past and current prices of cigarettes, alcohol and marijuana on the current demand for alcohol and marijuana. She finds higher past cigarette prices have a negative and significant effect on the current decision to use alcohol and marijuana providing some evidence of a gateway effect (or causal link) between cigarettes and these two drugs. DeSimone (1998) uses the 1984 and 1985 NLSY to examine the effect of past marijuana use on current demand for cocaine. He uses detailed information about the individual and local price information as instruments in a two-stage estimation process. His estimates suggest that prior marijuana use increases the likelihood of cocaine initiation 4 years later even after one controls for unobserved individual characteristics. This again provides evidence supporting the gateway hypothesis.

4. An economic model of gateway effects
It is clear from the behavioral psychology literature that an adolescent may have several different motivations for initiating substance use, including peer pressure, curiosity, rebelliousness or a desire to become intoxicated. Similarly, the economics literature demonstrates that the availability of particular substances is an important determinant because an adolescent can only ini-
tiate use of a drug by gaining access to it. The model of adolescent substance use we propose combines aspects of both these literatures into a general framework that generates testable hypotheses regarding the inter-temporal (gateway) and contemporaneous relationship between demands for alcohol, cigarettes, marijuana and cocaine. The theory assumes that individuals try to maximize their overall happiness, or utility, which is a function of the goods they desire. It further assumes that although individuals have limitless desires, they have limited budgets so individuals are forced to make choices among competing alternatives. Some of those alternatives include using alcohol, cigarettes, marijuana and cocaine. Unlike consumption of most goods examined by economists, the use of a substance such as alcohol or marijuana may be reinforced over time because of the physiological, emotional and behavioral effect that accompanies its consumption. What this means is that the decision to use a substance today may also influence the individual’s decision to use the substance tomorrow. Furthermore, an individual may develop a tolerance for a particular substance so that more of the substance must be consumed in the future in order for the person to get the same level of enjoyment (intoxication) from its consumption.

The model outlined above is a variation of the rational addiction framework developed by Stigler & Becker (1977) and Becker & Murphy (1988) and can be written more formally as follows:

\[ \text{max}_{Y, A, T, M, C} \sum \beta^t \left[ U(Y_t) + b_t V(A_t, T_t, M_t, C_t, S_t) \right] \]  \hspace{1cm} (1)

subject to:

\[ \sum R^t I^t = \sum (Y_t + P_{Al} A_t + P_{Tr} T_t + P_{Ml} M_t + P_{Cl} C_t) \]  \hspace{1cm} (2)

\[ R^t = \left( l(l + r)^{-1} \right) \]  \hspace{1cm} (3)

\[ b_t = G(Z_t, \delta_t) \]  \hspace{1cm} (4)

\[ S_t = (A_{t-j}, T_{t-j}, M_{t-j}, C_{t-j}); j = 1, \ldots, t \]  \hspace{1cm} (5)

Equation (1) indicates that individuals obtain utility out of consuming each of these substances and that the amount of utility they obtain potentially depends on the history of consumption of these products. The variable \( \beta^t \) represents the individual's discount factor on future consumption of goods and is assumed to be less than one, indicating that consumption today is valued more than consumption in future periods [it also assumes exponential discounting, implying stable preferences over time. Alternative methods of discounting have been suggested, although no formal empirical test of these competing models have been made]. \( U \) and \( V \) are subutility functions that are assumed to be 'well-behaved' [technically, this requires certain assumptions about the signs of the first and second derivatives of the utility functions]. The variable \( b_t \) represents factors that influence the individual's marginal utility, or incremental happiness, from consuming drugs. These factors include observable characteristics, represented as \( Z_t \), such as one's age, religious upbringing or family structure, as well as the legal risks associated with consuming substance \( i \), represented as \( \gamma_a \). Finally, it is possible for unobservable characteristics, or individual heterogeneity, to influence the relative happiness of consuming particular substances. This individual heterogeneity is captured in the model by \( \alpha \).

Equation (2) is the individual's life-time budget constraint where prices are normalized so that the price of the composite consumption good equals one. Income in period \( t \) is given by \( I_t \) and \( P_{it} \) represents the monetary price of the substance, for \( i = A, T, M \) and \( C \). The variable \( R^t \) represents the budgetary discount factor that puts all future monetary values into current dollar value using the market rate of interest \( r \).

Equation (5), which defines the structure of the past consumption stock, represents the cumulative past consumption of all the substances, although it is assumed that each substance will have its own rate of depreciation. It is this singular capital stock that represents a major modification to previous economic theories of rational addiction and habit formation because it allows past consumption of one drug to influence the marginal utility (or incremental happiness) of consuming another drug. This means that reinforcement can take place across substances, although it does not necessarily have to. The implications of a singular past capital stock are discussed in detail in Pacula (1997, 1998b). The most important implication has to do with the
decision to initiate consumption of a drug. Economic theory postulates that an individual will only initiate consumption of a drug when the marginal utility of consuming that drug is greater than its marginal cost (the incremental cost of obtaining that good). In the case of a single consumption stock variable, the marginal utility of initiating consumption of a new drug is higher, ceteris paribus, when there is past consumption of another drug that contributes to the single past consumption variable (see Pacula, 1997). The implication of this within the current context is that the drug with the lowest marginal cost will be the drug that is initiated first. For most adolescents, the lowest cost substances are alcohol and cigarettes. However, the model predicts that once consumption of these early drugs is initiated, the marginal utility associated with trying a new substance, such as marijuana or cocaine, rises. For a fixed marginal cost, the individual becomes more likely to initiate use of these more costly substances as the marginal utility of using them rises.

The particular sequencing of drug use, commonly referred to as the gateway effect, can be explained in this model by differences in the marginal cost of consuming particular substances and the cross-drug reinforcement associated with a multi-substance habit. Adolescents initiate their drug use with substances that are legal for adults because these substances have the lowest marginal cost, so for a given marginal utility of consumption, there is a greater likelihood that marginal utility is greater than marginal cost. Further, this model can be used to explain why we see why some adolescents choose never to initiate marijuana or cocaine use even though they use alcohol and/or cigarettes. It is possible that the rates of depreciation on prior consumption of alcohol and/or cigarettes are so large that this prior consumption has very little impact on future marginal utility. In other words, these adolescents are not prone to addiction. Alternatively, it may be the case that for some individuals the marginal cost of initiating these illegal substances is so high that even though the marginal utility of consuming the substances rises, it still remains well below the marginal cost. One very important implication of this model, therefore, is that any substance can serve as a so-called gateway drug provided it has a relatively low marginal cost.

Structural demand equations, derived from the maximization problem outlined in equations (6)–(9), are a function of all current prices, legal risks, past and future consumption of the drugs, income, the observable characteristics influencing the marginal utility of consuming each drug and individual heterogeneity:

\[ A_t = f(P_{A_0}, P_{T_0}, P_{M_0}, P_{C_0}, \gamma_{A_t}, \gamma_{T_t}, \gamma_{M_t}, \gamma_{C_t}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, I_0; Z, \alpha) \]  \( (6) \)

\[ T_t = f(P_{A_0}, P_{T_0}, P_{M_0}, P_{C_0}, \gamma_{A_t}, \gamma_{T_t}, \gamma_{M_t}, \gamma_{C_t}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, I_0; Z, \alpha) \]  \( (7) \)

\[ M_t = f(P_{A_0}, P_{T_0}, P_{M_0}, P_{C_0}, \gamma_{A_t}, \gamma_{T_t}, \gamma_{M_t}, \gamma_{C_t}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, I_0; Z, \alpha) \]  \( (8) \)

\[ C_t = f(P_{A_0}, P_{T_0}, P_{M_0}, P_{C_0}, \gamma_{A_t}, \gamma_{T_t}, \gamma_{M_t}, \gamma_{C_t}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, A_{t-j}, T_{e-j}, M_{e-j}, A_{t+j}, T_{e+j}, M_{e+j}, I_0; Z, \alpha) \]  \( (9) \)

for \( j = 1, \ldots, m \) and \( t = 1, \ldots, T \).

It is clear from this system of equations that, if correctly identified, one can examine the impact of the past consumption of any drug on the current consumption of that and other drugs as well. However, as is discussed below, identification of this system of equations is complex.

5. Estimation issues
5.1 Estimation of the structural demand equations with myopic and rational addiction

In order to estimate these structural demand equations it is necessary to have longitudinal data with repeated information over time on the consumption of a number of substances. In each of equations (6)–(9) the dependent variable is the current consumption of a particular substance. The right-hand side equations include the past and future consumption of that substance and other substances. If, for example, the coefficient on the past consumption of cigarettes is important in explaining the current consumption of marijuana this would be evidence of a gateway effect from cigarettes to marijuana use. It is important to point out that should such a
statistical relationship exist, it would be after controlling for the past consumption of cigarettes. Consequently, if there was some unobserved individual factor that contributed to the use of both cigarettes and marijuana, the past consumption of cigarettes would potentially capture this unobserved propensity to smoke cigarettes.

In myopic models of addictive behavior the past consumption of a good leads to current consumption of a good, but individuals ignore the future implications of this current consumption. Within rational addiction models, individuals anticipate that current consumption might change the marginal benefits of future consumption and make decisions with this information. This “future causes the past” is incorporated into equations (6)–(9) by the inclusion of the future consumption levels as explanatory factors in current consumption. It is in this sense that equations (6)–(9) can be used to test for both myopic addiction and rational addiction. The significance of the coefficients on future consumption helps distinguish these two models. This distinction is important for policy because the rational addiction model suggests that consumers will see that price increases not only affect the cost of current consumption but also of future consumption.

One of the key challenges in testing for rational addiction or gateway effects in equations (6)–(9) is deriving methods to obtain unbiased estimates of the coefficients on the past and future consumption variables. Due to time persistent unobserved heterogeneity and endogeneity these right-hand side variables are likely to be correlated with the error terms in each equation leading to biased estimates using conventional ordinary least squares. There are several ways to address this problem.

The first is to utilize a two-stage instrumental variable technique. Of course, the instrument must not be correlated with the unobserved heterogeneity causing the identification problem in the first place. Moreover, valid instruments are those variables that have a direct effect on past or future consumption but have no direct impact on current consumption. The logic of the instrumental variable approach is that the researcher can trace the impact of changes in this instrumental variable on changes in the past consumption of a substance and then the subsequent impact of the past on changes in the current levels of this and other substances. Since the instrumental variable does not directly impact the current consumption levels, any contemporaneous affect between the instrument and current levels can be attributed to the causal path of how past consumption influences current levels of consumption. In this case, we obtain identification of the gateway effect but are unable to measure the degree to which prior use increases current consumption.

In a model of substance abuse, especially for youth, there are several instrumental variables that are likely to meet the condition that they affect past or future consumption but have no direct impact on current consumption. Past and future prices can be used as instruments for past and future consumption levels. In this case we predict past consumption based on all exogenous variables as well as past prices. Past prices should not directly impact current consumption except through their impact on past consumption. Moreover, past prices should be uncorrelated with time persistent individual unobserved heterogeneity, assuming that prices are determined in the market place and can not be influenced by individual behavior. The same argument holds for future prices of each substance serving for an instrument for future consumption.

A variety of school environmental factors might be used as instrumental variables if one were to examine this model for a population of high school students. Consider a situation where longitudinal data are available on youth in the 8th grade to the 12th grade [an example of this type of dataset is provided in section 6 of this paper]. In this case the dependent variables in equations (6)–(9) might be the 10th grade consumption of each substance. The right-hand variables would include the 8th and 12th grade consumption levels of each substance. This type of data would allow for another set of instrumental variables to be used to identify the impact of 8th and 12th grade consumption of all substances on the 10th grade consumption of each substance.

Since many of these individuals change schools during their progression from 8th grade to 12th grade, school environmental variables may influence early consumption but no longer have a direct impact on current consumption. Consider, for example, a variable that indicates whether an 8th grader is in a school where they are the oldest students in the school (i.e. a
middle school servicing 6th–8th graders). In this case, exposure to older students may influence early consumption (past consumption) but not directly affect their consumption when they are in 10th grade. Another example is the proportion of individuals in the 8th grade school that use each of these substances. This is likely to influence the pressure faced by an individual student to try these substances in 8th grade. These variables, however, should not be included in the 10th grade use equation since the 10th grade school is often different to the 8th grade school. Consequently, the 8th grade school environment affects 8th grade substance use but does not affect 10th grade substance use except for the possible gateway affect, that 8th grade substance use leads to 10th grade use of other substances. In other words, the only way that the 8th grade school environment should impact on current substance use is through its impact on 8th grade substance use (which might lead to 10th grade use).

There are a number of identifying restrictions that can be used in the instrumental equation for future consumption. One of the key advantages of panel data is that we would observe 12th grade variables for individuals when they were in the 10th grade. A number of 12th grade variables are likely to affect 12th grade consumption but should not be included in the 10th grade equation. For example, income available to the student in 12th grade is likely to affect the use of substances in 12th grade but should not affect 10th grade use since the income has not yet been earned. Whether a student is employed in 12th grade is another example. These and other similar variables would be included in the instrument equation for 12th grade consumption of each substance but not in the 10th grade substance use equations (6)–(9).

A number of testable hypotheses may be generated from equations (6)–(9). For example, one could test the importance of a joint capital stock by testing the significance of past consumption of one drug in the current demand for another. It may be that the rates of depreciation differ so much that only the cumulative effects of particular drugs influence the current decision to use substances. The assumption of rationality for adolescents could be tested by examining whether a change in future consumption and/or prices significantly influences current consumption. The contemporaneous relationship between particular drugs could be determined by examining contemporaneous cross-price effects.

5.2 Estimation of reduced form demand equations
In the framework outlined above it is also possible to forego estimation of the structural demand equations and estimate reduced form models for each substance. These models are identical to the models presented above except that past and future consumption of each substance are not included on the right-hand side of each equation. Instead, policy variables, such as past and future cigarette taxes, past and future alcohol taxes and other similar variables are included to replace these variables. These models examine, directly, the influence of past prices of all substances on the current use of any one substance. For example, the approach will answer the question: controlling for other factors, do students who face higher prices for cigarette, alcohol, marijuana and cocaine in the past use less marijuana now and in the future? The results from the structural and reduced-form models complement each other by helping us understand the mechanisms by which policies reduce youth substance demand. The advantages to the reduced-form estimation procedure is that the simpler econometric specification still provides evidence of the impact of policy variables on substance abuse.

6. Conclusion
We have presented a general economic theory of multi-substance use, one that incorporates the potential for myopic and rational addiction as well as gateway effects from one drug to another. This model was followed by a discussion of what types of data would be needed to estimate these effects and the difficulty of using data to identify addiction and gateway affects.

The general economic theory of multi-substance use has several further implications that might guide empirical work in the area. The model suggests that youth are likely to start with a drug that has a low marginal cost of use. Although the model is based on the economics paradigm, it has the flexibility to incorporate important insights from other disciplines. For example, it is likely that social and peer pressures might make early use of one drug particularly attractive for certain race or sex groups. In this
case the model predicts different patterns of gateway effects by race and sex and it is flexible enough to permit these types of race and sex differences. In fact, epidemiological studies suggest that in terms of progression into illicit drug use alcohol is more important for males and tobacco is more important for females (Kandel & Yamaguchi, 1993). Theories from sociology, epidemiology, psychology and others can all help guide this general model of multi-substance use.

The complexity of the system model presented above requires a very rich dataset for it to be implemented. Current publicly available datasets are not ideal for estimation of this model for several reasons. First, the most important data limitation of many datasets is that they are cross-sectional and do not follow the substance use behavior of a single cohort over time. Secondly, the ideal data would contain substance use measures for students in grade school. Some of the more useful data begin to collect data for 8th graders but ideally one would begin earlier when students are in grade school. Thirdly, the ideal data-set would collect information in shorter time intervals. Although the NELS:88 and MTF data track individuals over time, there is a 2-year interval between interviews. Given the rapid increase in the use of all substances during high school, identification of gateway effects would be greatly facilitated with yearly observations. Fourthly, due to the plethora of factors that influence substance use, the data need to be rich in personal and environmental variables. The NELS:88 data is a good example of a dataset that contains this type of information. The data include variables that reflect student characteristics, parent characteristics, as well as school characteristics. Finally, the ideal dataset would have a relatively long time horizon. One of the weaknesses of the NELS:88 data, for example, is that the some of the drug use questions are available for only two time periods (the 10th and 12th grade) making identification of gateway effects difficult. Longer longitudinal data would be especially helpful as researchers attempt to better understand the determinants of drug use.

Notes
[1] The price elasticity of demand also appears to vary across types of alcoholic beverages. In the review by Manning et al. (Appendix A, 1991) estimated price elasticities are between $-0.8$ and $-2.0$ for spirits, $-0.64$ and $-1.0$ for wine and $0.24$ to $-0.6$ for beer. Important tobacco demand studies include Schneider, Klein & Murphy (1981), Lewit & Coate (1982), Baltagi & Levin (1986) and Wasserman et al. (1991). Leung & Phelps (1993) is another excellent review of the growing body of research on alcohol demand.

[2] Although the Institute of Medicine (1994) recommends substantially higher cigarette taxes, they are careful to point out that the research base is thin: “The conflicting results of the few US studies that have examined the impact of cigarette prices on consumption by adolescents ... reinforce the need for new research to assess the potential for using higher tobacco taxes to deter adolescent tobacco use.”

[3] This is one of several NBER working papers that we cite in our paper. These working papers are available on the NBER web site at www.nber.org.

[4] Lewit et al. (1997) and Center for Disease Control (CDC) (1998) reach somewhat mixed results. Lewit et al. (1997) use data from surveys conducted in 1990 and 1992 in conjunction with the Community Intervention Trial for Smoking Cessation (COMMIT). They report a statistically insignificant effect of price on smoking participation for the full sample, but when they split the sample they find a statistically significant and large effect for boys but a small and insignificant effect for girls. They also find that high prices are associated with reductions in the intent to smoke among young non-smokers. CDC pool data from multiple cross-sections of the National Health Interview Survey. For all adults they find a small and statistically insignificant price effect for non-Hispanic white smoking in a very large sample ($N = 281,482$) but strong effects for Hispanic adult smoking. They report a statistically significant effect of price for young adults pooled across race/ethnicity, but state that the pattern across race/ethnic groups was consistent across all age groups. From their published Figure 1 (CDC, 1998, p. 608) it appears that higher prices have a small effect on smoking by non-Hispanic white young adults.

References
Centers for Disease Control and Prevention


NATIONAL PARENTS' RESOURCE INSTITUTE FOR DRUG EDUCATION INC. (1996) student use of most drugs reaches highest level in nine years—more report getting “very high, bombed, or stoned”, Press Release, 25 September 1996.


