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ABSTRACT

This research analyzes the contemporaneous and intertemporal relationship between the demands for alcohol and marijuana by youths and young adults. A general theory of multi-commodity habit formation is developed and tested using data from the 1983-1984 waves of the National Longitudinal Survey of Youth. An Adjusted Tobit specification is employed for estimating the empirical model. Habit persistence is distinguished from unobserved heterogeneity through a reduced form instrumental variable technique. The results show that higher beer prices significantly reduce the demand for both alcohol and marijuana, indicating a contemporaneous complementarity between these two substances even after controlling for commodity-specific habit formation. Further, prior use of alcohol and cigarettes significantly increases the likelihood of currently using marijuana, providing evidence in support of the gateway hypothesis.

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I. Introduction

Substance use researchers have identified three empirical regularities from national surveys on drug use behavior that are frequently used to motivate specific drug policies. First, individuals who report currently using illicit drugs generally also report use of legal substances, particularly alcohol. Second, individuals who experiment with legal substances at a very young age are more likely to become involved with illicit drugs in later years. Third, despite differences in gender and ethnicity, individuals report a surprisingly consistent pattern of experimentation with drugs, with people generally reporting use of legal substances before illicit substances. These three findings suggest that both a contemporaneous and an intertemporal relationship exist between the consumption of legal and illicit substances. Understanding the nature of these relationships is important if we hope to develop an effective, comprehensive drug policy.

Recent restrictions on adolescent drinking, and in particular the Federal Uniform Drinking Age Act of 1984 and the 1991 increase in the Federal excise tax on beer, have generated some debate regarding the impact these policies have on the consumption of marijuana and other illicit substances by youths. Although it is widely accepted that these policies were effective at reducing youth alcohol consumption and some of the negative externalities associated with it, little is known about the impact these policies have had on the consumption of marijuana and other illicit substances.

This research analyzes the contemporaneous and intertemporal relationship between the demands for alcohol and marijuana by youths and young adults so that it is possible to determine what influence recent alcohol policies have had on the consumption of marijuana. Central to this analysis is the determination of economic substitutability and/or complementarity. This paper

presents a general model of adolescent substance use that allows for the possibility of multi-commodity habit formation. In this model, early experience with alcohol may change the individual's "tastes" for other drugs. A system of individual level demand equations are derived and empirically tested using micro-level data from the National Longitudinal Survey of Youth. The nature of the contemporaneous and intertemporal relationship between the demands for alcohol and marijuana are determined through the analysis of cross-price effects. It is found that previous experience with alcohol and cigarettes significantly increases the current probability of using marijuana, providing evidence in support of the so-called gateway hypothesis. The finding with respect to the impact of previous alcohol consumption on marijuana use, however, is only significant at the 10% level for a one-tailed test. Further, it is found that alcohol and marijuana are contemporaneous complements, not substitutes, even after controlling for commodity alcohol and marijuana use plays a bigger role in the decision to use marijuana than prior consumption of alcohol. These results imply that a one dollar increase in the tax on twenty-four 12-ounce cans of beer ($0.25 increase per six pack) in 1984 would have reduced the unconditional demand for alcohol by 15.2% and the unconditional demand for marijuana by 14.5% among youths and young adults.

II. Background

Several empirical studies suggest that cigarettes and alcohol are "gates" through which users move from nonuse of drugs to the use of illicit substances (Kandel 1975; Kandel and

Maloff, 1983; Smith 1992; Ellickson, Hays and Bell, 1992; Kandel and Yamaguchi, 1993). The gateway hypothesis tries to explain why adolescent involvement with drugs tends to follow a particular sequence, with adolescents using beer or wine first, then cigarettes or hard liquor, then marijuana, and finally more illicit substances. It postulates that it is the early use of legal drugs that causes adolescents to experiment with harder substances later (Kandel 1975).

The persistence of the gateway hypothesis as an explanation of adolescent drug involvement stems from studies that examine the timing of initiation of use for particular substances. These studies have found an amazingly consistent pattern of experimentation with drugs even across gender and ethnicity (Kandel and Yamaguchi, 1993; Ellickson, Hays and Bell, 1992). For example, Ellickson, Hays, and Bell (1992) find that the majority of adolescents follow the common sequence of (1) initiation of alcohol or cigarettes (with alcohol generally preceding cigarettes), (2) initiation of marijuana, (3) increased levels of drinking, (4) use of pills, (5) increased levels of cigarette use (weekly), (6) initial use of cocaine, and (7) initial use of other illicit drugs followed by regular use of marijuana. The pattern is robust across youths of various ethnic backgrounds, with only minor differences in the timing of harder substances. Not every adolescent who uses tobacco and/or alcohol necessarily decides to try other illicit substances. Individual characteristics and environmental factors play important roles in determining how far an individual progresses. It is important, therefore, for these factors to be controlled when one analyzes an individual's drug use behavior.

A number of recent economic studies examine the contemporaneous relationship between the demands for alcohol and marijuana. Using state-aggregated panel data from the Monitoring

the Future Survey, DiNardo and Lemieux (1992) estimate a bivariate probit specification of current alcohol and marijuana use.[1] They find that increases in the minimum legal drinking age over the years 1980-1989, which increased the implicit cost of consuming alcohol, caused adolescents to increase their consumption of marijuana. Chaloupka and Laixuthai (1994) "confirm" the short-run substitutability of marijuana for alcohol in their estimation of an ordered probit of the frequency of alcohol use using micro-level data from the Monitoring the Future data set. In their frequency equation for alcohol they include a decriminalization dummy variable to represent the legal risk of consuming marijuana.[2] The decriminalized dummy has a negative and significant coefficient implying that individuals living in a decriminalized state are less likely to consume alcohol frequently because marijuana is relatively cheaper.

Model (1993) also finds evidence of a substitution effect between alcohol and marijuana using SMSA-level data on emergency hospital room drug episodes collected by the Drug Abuse Warning Network. She finds that hospital emergency room episodes involving alcohol use are significantly lower in states with decriminalization statutes than in those without. Further, she finds significantly more marijuana-related episodes in decriminalized states than in non-decriminalized states.

Thies and Register (1993) are the first to use individual level data to estimate both the prevalence and quantity of marijuana consumed, and they find inconclusive evidence regarding

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[1] Use was defined as having used the substance in the previous thirty days.

[2] Chaloupka and Laixuthai also include some measures of the monetary cost of using marijuana in their 1989 equations. Their results differed depending upon whether the retail or wholesale price of marijuana is included. When the wholesale price is used, this variable had a positive and very significant coefficient on the ordered probability equation indicating a substitution effect. When the average retail price of marijuana is used, however, the coefficients on both the marijuana price variable and the decriminalization dummy variable are insignificant in all but the heavy drinking equation. The results in the heavy drinking equation again support a substitution effect.

the relationship between alcohol and marijuana. Using data from the 1984 and 1988 waves of the National Longitudinal Survey of Youth, Thies and Register use logit specifications to estimate the probability of currently using alcohol, being a heavy drinker, using marijuana and using cocaine. State decriminalization status, the minimum legal purchasing age for alcohol, and an aggregate index of enforcement are included as measures of state controls of drugs; no proxies of the monetary prices of these drugs are included. They find that individuals living in a decriminalized state are less likely to report currently using alcohol and cocaine in 1984, but they are not more likely to report using marijuana, making it difficult to interpret the significance of decriminalization in the alcohol and cocaine equations. In 1988, state decriminalization status only significantly influences the probability of using alcohol heavily. The findings with respect to legal drinking age status do not provide any additional insight. Underage individuals are significantly less likely to report currently using cocaine, but their legal status has no significant effect on the probability of using alcohol or marijuana. Coefficient estimates from Tobit specifications of the quantity of each drug consumed reveal that state decriminalization status has no significant effect on the quantity of alcohol or marijuana consumed, although it does significantly reduce cocaine consumption in the 1984 sample. Likewise, legal status for alcohol purchases has no significant effect on the quantity of any of the drugs consumed.

Pacula (forthcoming) builds on Thies and Register's (1993) work by estimating individual demand equations for alcohol and marijuana that include proxies for the monetary price of cigarettes, beer and marijuana using the 1984 NLSY. Like Thies and Register, she finds that individuals living in decriminalized states are less likely to report currently using alcohol but

they are no more likely than individuals living in nondecriminalized states to report currently smoking marijuana. She does find, however, that the beer tax has a negative and significant effect on the probability of using both alcohol and marijuana as well as the conditional quantities consumed, suggesting that alcohol and marijuana may be contemporaneous complements, not substitutes. Saffer and Chaloupka (1995) find similarly conflicting evidence in their estimation of the likelihood of using alcohol and marijuana using data from the 1988, 1990 and 1991 surveys from the National Household Survey on Drug Abuse. They include measures of the price of cocaine and heroin in their analysis of the demand for alcohol, marijuana, cocaine and heroin, and find that one out of six coefficients for marijuana and alcohol indicate complementarity and one coefficient indicates substitutability.

A major shortcoming of previous work using micro-level data is that they neglect the influence of past consumption on current use. If drug consumption is generally habit forming, then it is possible that consumption of one drug may lead to the subsequent use of another drug. Recent findings with respect to the patterns of experimentation suggest that this intertemporal relationship may not be insignificant. This study is the first to include measures of previous alcohol and marijuana consumption in the current demand for both of these drugs. It attempts to address some of the unanswered questions surrounding the observed patterns in substance use. In particular, it tries to determine if the sequencing in drug use is a function of multi-commodity habit formation or individual heterogeneity.

III. The Theoretical Model

Although previous studies have analyzed single drug consumption as an outcome of a habit forming process (Stigler and Becker 1979; Pollak 1970, 1976; El-Safty, 1976; Hammond, 1976; Houthakker and Taylor, 1970, Becker and Murphy 1988; Becker, Grossman, and Murphy 1991; Chaloupka 1991; and Moore and Cook 1995), this is the first paper to use a general model of multi-commodity habit formation to study polysubstance use. The theoretical analysis is limited to the consumption of only two drugs, alcohol and marijuana, so that direct implications of the model may be tested using data from the National Longitudinal Survey of Youth. The theoretical model may be extended to include additional goods that contribute to the habit of interest.[3]

The following model builds on the framework developed by Pollak (1970, 1976) and Houthakker and Taylor (1970). Tastes are allowed to change with the prior consumption of either drug. Technically, this means that the consumption stock variable enters directly into the period specific utility function instead of using the household production framework. Although the debate regarding the appropriateness of assuming endogenous tastes is far from over, Phlips (1983) has shown that the mathematics are the same regardless of the approach. Further, it is assumed here that youths behave myopically, and therefore maximize their instantaneous utility instead of their lifetime utility functions.[4] Previous tests of the rational addiction model have

3 The empirical analysis includes the price of cigarettes so that it is possible to control for the potential relationship these demands may have with cigarettes. There is insufficient data to estimate individual level demand equations for cigarettes in the NLSY for the years being analyzed here, so the theoretical model focuses on the demand equations being estimated.

4 For a discussion of multi-commodity habit formation within a rational addiction framework, see Pacula (1997).

found that youths generally ignore the impact of future events on current consumption of alcohol and cigarettes (Becker, Grossman and Murphy, 1991; Chaloupka, 1991).[5]

Like previous models, utility is assumed to be separable in general consumption and drug consumption.[6] If we let A_t represent an individual's alcohol consumption, M_t represent the same individual's marijuana consumption, C_t represent the consumption of a general composite good, and S_t represent the consumption capital stock, the problem facing the youth is to maximize his period specific utility function subject to his budget constraint.

$$(3.1) \quad max_{C_t,\, A_t,\, M_t} \quad U(C_t) + b_t\, V(A_t, M_t, S_t)$$

subject to:

$$(3.2) \quad Y_t = C_t + P_{At} A_t + P_{Mt} M_t$$

$$(3.3) \quad S_t = (A_{t-j}, M_{t-j}); \quad A_0, M_0 \text{ given}, j = 1, \ldots, t.$$

$$(3.4) \quad b_t = G(Z_t, \gamma_t, \alpha)$$

U and V are subutility functions where $U' > 0$, $U'' < 0$, $V'_A \geq 0$, $V'_M \geq 0$, and $V'' < 0$. The variable b is a function of factors that influence the individual's marginal utility of consuming drugs, as given by equation (3.4). Z_t represents the observable individual-specific effects, γ_t represents observable, nonmonetary price effects and α represents the remaining unobservable heterogeneity.

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[5]Grossman and Chaloupka (1997) find that youths do behave rationally in the case of cocaine consumption. The estimated price effects found here, therefore, should be thought of as a lower bound if youths do, in fact, behave rationally with respect to their polysubstance use.

[6]One could argue that utility should not be made separable, since consumption of marijuana or alcohol may increase the marginal utility of, say, recreation time. Since this simple model ignores the labor-leisure choice by using a composite consumption good, it would be impossible to calculate the elasticities of substitution between particular goods and drugs.

Equation (3.2) is the individual's lifetime budget constraint where prices are normalized such that the price of the composite consumption good, C_t, is equal to one. P_{At} and P_{Mt} are the monetary price of alcohol and marijuana, respectively. Unlike other goods sold in the market, alcohol and marijuana are illegal, at least for adolescents. Since these goods must be purchased secretly, prices are not likely to be homogeneous across individuals or across locations. Both the monetary price of a particular drug (P_t) and the cost of consuming it (γ_t) will vary across individuals.[7] Since the nonpecuniary costs of using these drugs are not measured in dollars, these costs are not reflected in the budget constraint. Instead, they are incorporated into the marginal utility shifter, b_t. It is possible, therefore, for b_t to be negative for a given individual. Time subscripts are included to reflect that both cost components may change over time, although it is assumed in the model that the adolescent has no control over how these costs change over time.

Equation (3.3), which defines the structure of the capital stock, represents a major modification to previous theories of habit formation. S_t represents the cumulative influence of past consumption of *both* drugs. Instead of having two independent capital stocks, one for each drug, a multi-commodity habit will have a single capital stock that can be written as some combination of the individual capital stocks for each commodity. Even if this composite stock is simply a linear combination of the two separate drug stocks there are important implications for the model because past consumption of alcohol (marijuana) can then influence the marginal

[7]The monetary price of a drug reflects only those costs and risks borne by the seller. It is likely that additional costs and risks will exist for the adolescent who chooses to consume these drugs. These costs must also be incorporated into the final price of the drug. For many adolescents, environmental factors can influence the relative price of obtaining an illegal substance as well as the likelihood of trying or using one.

utility of consuming marijuana (alcohol). The significance of a single capital stock can be seen by analyzing the first-order conditions[8]:

(3.5) $U'(C_t) - \lambda_t = 0$

(3.6) $b_t \; V'_A (A_t, M_t, S_t) - \lambda_t P_{At} \leq 0$

(3.7) $b_t \; V'_M (A_t, M_t, S_t) - \lambda_t P_{Mt} \leq 0$

(3.8) $Y_t - C_t - P_{At} A_t - P_{Mt} M_t = 0$

Equations (3.6) and (3.7) show that the existence of a single consumption stock variable implies that prior use of alcohol and marijuana can influence the individual's current decision to use both of these substances in the current period.

For a behavior to be habit forming, it must exhibit tolerance and reinforcement. Tolerance means that the utility associated with consuming a given amount of a particular drug today is lower, ceteris paribus, when past consumption of either drug is higher, or $\partial V_t / \partial S_t < 0$. Reinforcement, in the case of a multi-commodity habit, occurs when an increase in the past consumption of either drug increases the desire for current consumption of both drugs, or $\partial^2 V_t / \partial A_t \partial S_t > 0$ and $\partial^2 V_t / \partial M_t \partial S_t > 0$ (Iannaccone, 1984; Pacula, 1997). What this means is that the marginal utility of consuming marijuana (alcohol) will be higher if there is previous consumption of alcohol (marijuana). This has important implications on the individual's decision to initiate one of these substances. An individual will initiate consumption of a drug when the marginal utility of consuming that drug evaluated at zero consumption, is greater than

[8]Equations (3.6) and (3.7) are expressed as inequalities because of the individual's option to consume zero amounts of alcohol or marijuana.

the marginal cost. Inserting equation (3.5) into equations (3.6) and (3.7) and rearranging terms yields the following:

$$(3.9) \qquad \left.\frac{b_t V_A^{'}(A_t, M_t, S_t)}{U'(C_t)}\right|_{A_t=0} > P_{At}$$

$$(3.10) \qquad \left.\frac{b_t V_M^{'}(A_t, M_t, S_t)}{U'(C_t)}\right|_{M_t=0} > P_{Mt}$$

If drug consumption is generally habit forming, then the marginal utility of initiating consumption of a new drug is higher, ceteris paribus, when there is past consumption of the other drug than when there is no previous consumption of either drug. For example, if the adolescent has never consumed alcohol before initiating marijuana use then $S_t = 0$. The adolescent will initiate use of marijuana only if the immediate marginal utility of consuming it is greater than the immediate marginal cost. If the adolescent has consumed alcohol prior to time t, however, $S_t > 0$. This prior experience will increase the instantaneous marginal utility of initiating marijuana consumption in period t if using drugs is generally habit forming, and for a given marginal cost, the adolescent becomes more likely to initiate marijuana consumption.

Although the signs of $\partial^2 V_t / \partial A_t \partial S_t$ and $\partial^2 V_t / \partial M_t \partial S_t$ are theoretically ambiguous and need to be tested empirically, a model which allows for potential multi-substance habit formation provides a simple explanation for the gateway hypothesis. The particular sequencing of drug use

can be explained by differences in the marginal cost of consuming particular substances. Alcohol generally has a lower marginal cost, so there is a greater chance that $MU_A > MC_A$ when there has been no prior consumption of any substance. Once alcohol use is initiated, the marginal utility of consuming marijuana also rises because of the single past consumption stock and the positive reinforcement in consumption over time. For a fixed marginal cost of using marijuana, there is now a greater likelihood that the marginal utility of using marijuana is greater than its marginal cost. The youth may never go on to use marijuana, however, if the marginal cost of using it remains higher than marginal utility. Therefore, not all youths who use alcohol will necessarily progress into marijuana use. Other factors in the model, such as prices, income and depreciation, may preclude the ratio of marginal utilities of consuming marijuana from ever being greater than the marginal cost.[9] One implication of the model is that any drug can serve as a gateway drug. The only criterion is that the substance has the lowest marginal cost of all other drugs.

Reduced form demand equations look like the following:

(3.11) $A_t = g_1 (A_{t-j}, M_{t-j}, P_{At}, P_{Mt}, Y_t; \alpha, Z_t)$

(3.12) $M_t = g_2 (A_{t-j}, M_{t-j}, P_{At}, P_{Mt}, Y_t; \alpha, Z_t)$

for $j = 1,\ldots,m$. If adolescent substance use can be explained by a multi-commodity consumption effect, past consumption of both substances would enter positively and significantly into equations (3.11) and (3.12) after controlling for the effect of prices and individual heterogeneity.

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[9] The gateway effect would have a very different interpretation in the household production framework. Instead of assuming the adolescent's underlying tastes for the drug changes over time, one would instead conclude that the adolescent's early experience producing intoxication (finding a dealer, hiding the drugs, etc.) has generated some information or human capital that allows the adolescent to produce the same level of intoxication in the future at a lower shadow price. Although the marginal utility of consuming marijuana remains constant over time, the marginal cost of using it falls as the individual consumes more alcohol. Thus, the likelihood of initiating marijuana consumption increases over time.

Several factors make it difficult to sign the comparative statics for this model without imposing additional restrictions through functional form. Nonetheless, it is possible to consider the impact of a change in the price of alcohol in a simple two period model where alcohol and marijuana are first net substitutes and then net complements assuming the rates of depreciation of the two drugs are equal. Table 1 evaluates the impact of an increase in the price of alcohol in period 1. Looking first at the case where alcohol and marijuana are substitutes and the individual consumes positive amounts of both drugs in period 1, the increase in the price of alcohol in period 1 leads to a decrease in the quantity of alcohol consumed and an increase in the quantity of marijuana consumed in period 1. The impact on consumption of these drugs in period 2, however, is uncertain. Assuming that the rates of depreciation on alcohol and marijuana are equal, one would need to know whether $\Delta A_1^* <, >, or = \Delta M_1^*$. If the net effect on S_2 is negative because the change in alcohol consumption is larger than the change in marijuana consumption, then the increase in the price of alcohol in period 1 will lead to a decrease in the probability of using both substances in period 2. If, however, the net change in S_2 is positive, then the increase in price in period 1 will cause an increase in the probability of using both substances next period.

If habit formation is commodity specific, the impact on future consumption of both drugs is much clearer. The decrease in consumption of alcohol in period 1 will reduce the probability of using alcohol in period 2. Likewise, the increase in consumption of marijuana in period 1 will increase the probability of consuming marijuana in period 2. The uncertainty arises in the case

of multi-commodity habit formation because the change in both variables makes it unclear which direction S_2 as a whole will move. Thus, one needs to know the relative sizes of the changes.

If alcohol and marijuana are net complements, the impact of the price increase in period 1 is, again, much clearer. Both alcohol and marijuana consumption in period 1 will fall which will lead to a reduction in S_2. This reduced capital stock will mean that the probability of using alcohol and marijuana in period 2 will also decrease. If the adolescent only consumes alcohol in period 1, the decrease in consumption of alcohol in period 1 due to the increase in price will, again, reduce S_2, thus decreasing the probability that the adolescent consumes alcohol and marijuana in period 2. This is true whether these drugs are substitutes or complements. Thus, the structural state dependence across substances exists regardless of the contemporaneous relationship between the two drugs. These two effects may, however, offset each other.

Initial conditions matter in this model because they determine the size of the consumption stock in period 1. The higher the initial consumption stock, the higher the level of consumption in all future periods due to reinforcement. In other words, $A_t^{**} > A_t^{*}$ and $M_t^{**} > M_t^{*}$ for $t = 1, 2$.

IV. Empirical Specification

A. The Econometric Model

If we let X_{it} and W_{it} represent the observed characteristics and prices that influence individual i's decision to use alcohol and marijuana, respectively, linear approximations of the reduced form demand equations shown in equations (3.11) and (3.12) may be written as follows:

(4.1a) $$A_{it}^{*} = X_{it}\,\xi + \gamma_0\, A_{it-1}^{*} + \eta_0\, M_{it-1}^{*} + \alpha_i + \nu_{1i}$$

(4.1b) $$M_{it}^{*} = W_{it}\,\delta + \gamma_1\, A_{it-1}^{*} + \eta_1\, M_{it-1}^{*} + \alpha_i + \varpi_{1i}$$

(4.1c) $$ln\,(A_{it}) = \begin{cases} X_i\beta + \bar{\gamma}_0\, \ln A_{it-1} + \bar{\eta}_0\, \ln M_{it-1} + \alpha_i + \upsilon_{2i} & \text{if } A_{it}^{*} > 0 \\ -\infty & \text{if } A_{it}^{*} \le 0 \end{cases} \qquad i = 1, \ldots, N \text{ individuals.}$$

(4.1d) $$ln\,(M_{it}) = \begin{cases} W_i\Gamma + \hat{\gamma}_1\, \ln A_{it-1} + \hat{\gamma}_1\, M_{it-1} + \alpha_i + \omega_{2i} & \text{if } M_{it}^{*} > 0 \\ -\infty & \text{if } M_{it}^{*} \le 0 \end{cases} \qquad i = 1, \ldots, N \text{ individuals.}$$

where

(4.1e) $$(\nu_{1i}, \nu_{2i}) \sim N\begin{pmatrix} 0 \\ 0 \end{pmatrix}\begin{bmatrix} 1, & \rho_1\sigma_1 \\ \rho_1\sigma_1 & \sigma_1^{2} \end{bmatrix}$$

and

(4.1f) $$(\varpi_{1i}, \varpi_{2i}) \sim N\begin{pmatrix} 0 \\ 0 \end{pmatrix}\begin{bmatrix} 1, & \rho_2\sigma_2 \\ \rho_2\sigma_2 & \sigma_2^{2} \end{bmatrix}$$

Here, A_{it}^{*} and M_{it}^{*} represent an individual's true tastes for alcohol and marijuana at time t, respectively. The variables A_{it} and M_{it} represent the individual's observed quantities of alcohol and marijuana consumed, respectively. The observed quantities consumed are logged because the dependent variables are both highly skewed to the right. The skewness results from a small number of heavy users who consume very large quantities of the substances. The model presented above (4.1a) - (4.1f) is a variant of the Adjusted Tobit Model, which was first introduced by van de Ven and van Praag (1981). This model is designed to deal with highly skewed censored dependent variables.[10] The variable, α_i, represents individual i's unobserved factors that influence his tastes for drugs. This unobserved individual effect enters the theoretical

[10] The standard Tobit model performs poorly when the error term is not normally distributed. The skewness in the data when the dependent variables are not logged would certainly generate non-spherical error terms. A further advantage to using the Adjusted Tobit model is that it does not restrict a variable to have the same influence on the

model through b_i, the shifter to the marginal utility of drugs. No assumptions are made regarding the nature of this individual specific effect.

The parameters γ_i and η_i in equations (4.1a) - (4.1d) capture the influence of prior experience on the current consumption of both these drugs. It is the significance of these parameters that determines whether multi-commodity habit formation (state dependence) takes place. If only γ_0 and η_1 are significant, then the habit formation is commodity specific. If, however, η_0 or γ_1 are positive and significant, there is evidence of multi-commodity habit formation. The main question here, however, is whether γ_1 is greater than zero implying the existence of a gateway effect. Being able to consistently estimate these parameters, therefore, is of utmost importance.

The existence of habit formation in a model with unobserved heterogeneity complicates estimation procedures since past consumption experience is also a function of the unobserved heterogeneity. It becomes difficult to determine whether time dependence is generated by actual past experience with marijuana and alcohol (true state dependence) or from unobserved individual components that cause serial correlation of the error terms over time (spurious state dependence). Although estimation of the structural model outlined in equations (4.1a)-(4.1f) would yield a direct measure of the impact of prior consumption on current consumption of both drugs, the estimated coefficients would be extremely sensitive to the starting values of the lagged dependent variables because the number of time periods in the data is small (Chamberlain 1984).

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likelihood of using a substance as on the conditional quantity consumed. For more on the Adjusted Tobit model see van de Van and van Praag (1981) and Manning et. al (1987).

In this case it is more appropriate to use an instrumental variable technique if one wants to obtain consistent estimates (Chamberlain 1984; Heckman 1981).

Chamberlain (1978) showed that it is possible to distinguish models with state dependence from those with unobserved heterogeneity by using a simple instrumental variable (IV) technique to estimate reduced form demand equations. It is based on the assumption that, in the absence of state dependence, current consumption of a drug is independent of changes in exogenous lagged variables. So, in the case of alcohol and in the absence of state dependence, $E[A_{it} \mid X_{it}, X_{it-1}] = E[A_{it} \mid X_{it}]$. A change in the lagged beer tax, for example, will have no effect on the current consumption of alcohol even though it does influence the consumption of alcohol in the previous period. If current consumption is not affected by past consumption, then it should also not be affected by a change in the earlier price of beer. If this is not the case, then state dependence must exist. Notice that this test does not depend on any assumptions regarding the nature of the unobserved heterogeneity. As long as the lagged variable is independent of the individual specific heterogeneity, no serial correlation will exist in the error term. Coefficient estimates will, therefore, be consistent. It will not be possible, however, to measure the exact impact of previous consumption on current consumption using this model, only whether or not a structural relationship exists.

The Adjusted Tobit model presented above is estimated using this IV approach. Past prices for alcohol and marijuana are included instead of past consumption of alcohol and marijuana. Since it is important to use prices that are independent of the individual specific effect for consistency, measures of the past legal risk of using these substances are used.

B. The Data

The National Longitudinal Survey of Youth (NLSY) is a multistage stratified area probability sample representative of individuals who lived in the contiguous United States in 1979 and were between the ages of 14 and 21. The survey has 12,686 participants and includes youths who are often not represented in other surveys, such as high school dropouts and the unemployed. The same respondents have been interviewed annually through personal household follow-ups. The success rate for these interviews has been surprisingly high, with 95% of the original cohort reinterviewed in 1984 (Mensch and Kandel 1988). Anyone who was not present in the 1982, 1983 and 1984 surveys was dropped. This reduces the sample to 10,565 observations before observations are lost because of missing data.

Due to the nature of the survey, extensive information about the individual and his family is available. Of particular importance to this study are personal and family characteristics which have been found to be important to the individual's decision to use drugs, such as religious upbringing, parental supervision and family drinking patterns. Some variables, such as income, marital status and living arrangements, are potentially endogenous to the individual's decision to use drugs, so two forms of all the demand equations will be estimated throughout this study. A short form (SF) model will only include exogenous variables and a long form (LF) model will include potentially endogenous variables that also may be important to an adolescent's decision to use drugs. A description of the variables included in this analysis is provided in Table 2.

Questions regarding present and past alcohol use were included in all of the annual surveys during the period 1982-1985, and again in 1988, 1989 and 1992. Annual and thirty-day

prevalence marijuana use data are available in the 1984, 1988 and 1992 waves of the survey. In addition, the 1984 survey included questions regarding the individual's monthly use of marijuana during the years 1979-1984. Therefore, using these retrospective data, it is possible to construct a consecutive two year panel of data on alcohol and marijuana use from 1983-1984.[11] Although the retrospective data may be subject to recall error, comparisons of the constructed thirty-day prevalence statistic for 1983 with those obtained from the Monitoring the Future and the National Household Survey for the same year show that the data are comparable to these national surveys for the same age groups in 1983 (see Pacula 1995).

The reliability and validity of self-reported drug data has been debated for some time. Although one cannot verify that underreporting does not exist in the NLSY data, it has been shown that the alcohol and marijuana data are consistent with that obtained from other nationally representative surveys.[12] Variables, such as whether or not anyone else was present during the interview, have been included in the analysis to control for potential reporting biases.

C. Measures of Price

A series of price variables have been added to the NLSY data for purposes of this study. Two variables are added to capture the full price of alcohol. First, the real state tax on a case of twenty-four 12-ounce cans of beer, obtained from Brewers Almanac, is used to represent the real price of alcohol. Although beer is not the only form of alcohol consumed by adolescents, beer

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[11] It is the author's opinion that a panel constructed from the 1984, 1988 and 1992 surveys would introduce too much noise into the estimation period since there are four year gaps between observation points.

[12] For further discussion on the validity and reliability of self-reported data, see Midanik (1982,1988). For more on the validity of alcohol and drug data in the NLSY, see Mensch and Kandel (1988) or Crowley (1985).

accounts for well over half of all ethanol consumed (Cook and Moore 1993; Chaloupka and Laixuthai 1994; Grossman et al. 1993). Tax information was used instead of the actual real price of beer because it could better address policy questions and it has been found to have fewer errors in measurement than local price data. Previous studies have shown that the effect of price on the demand for alcohol is qualitatively similar regardless of whether price is defined as the beer tax, the real price of beer, or a weighted price index of beer, wine and distilled spirits.[13]

In addition to the real state beer tax, a dummy variable representing whether the individual was of legal age to purchase alcohol is included. Being of legal purchasing age should increase the demand for alcohol since legal restrictions no longer exist. Information regarding the states' minimum legal purchasing age was obtained from the Book of the States (1984-1985).

A difficult problem arises when trying to estimate the demand function for marijuana because reliable price data are not readily available. Therefore, proxies for both the legal risk and monetary cost are used to represent the full price. In recent work, Pacula (1995) introduced a relatively new but important proxy for the price of marijuana, the ratio of common crimes (measured as burglary plus robbery) to the number of officers at the Metropolitan Statistical Area (MSA) level.[14] This ratio captures the relative enforcement risk of dealing, possessing and consuming drugs. It has been shown that this measure of enforcement risk is positively related to the maximum, minimum and median price of marijuana (Pacula 1995). Since marijuana can be produced relatively cheaply, the largest component of the monetary price of marijuana is

[13] See Grossman, et al. (1993) for a review. Grossman et al. (1987) found that 100% of the tax on beer is passed on to the consumer in higher prices. Thus, any change in the tax would represent an increase in the price the consumer faces.

[14] These data were obtained from the Uniform Crime Reports published by the U.S. Department of Justice.

determined by the risk premium bringing the drug to market. A decrease in the number of crimes per officer increases the risk of getting caught selling marijuana, which increases the price of marijuana, and decreases the quantity of marijuana consumed.

In addition to the ratio of crime to officers, a dummy variable set equal to one in those states where marijuana consumption has been decriminalized is also included.[15] Previous studies have relied heavily on the performance of this variable in determining the relationship between an individual's alcohol and marijuana consumption, although recent research suggests that this may be an inadequate proxy of the legal risk faced by youths (Pacula 1995; Saffer and Chaloupka 1995). Possession of small amounts of marijuana for personal use is not a felony in decriminalized states, although it may still be a crime. Individuals who are caught possessing up to an ounce of marijuana are given a fine ($0 - $250) but are not required to serve any jail time. The size of the fine typically depends on the number of prior marijuana offenses. States that do not have decriminalization statutes vary significantly in their penalties for possession.

The final price included in this study is the state-level price for a pack of cigarettes, including state and federal taxes. This information was obtained from The Book of the States (1984-1985). Since it is possible that cigarettes act as a gateway drug, and not alcohol, it will be important to control for the prior consumption of this alternative substance. Cigarette consumption is only reported in the NLSY in 1984, so it is not possible to construct a two-year panel for cigarette demand.

[15]There are 11 states that were decriminalized in 1984: Alaska, California, Colorado, Maine, Minnesota, Mississippi, Nebraska, New York, North Carolina, Ohio and Oregon (Kleiman, 1992). Selling and manufacturing marijuana in decriminalized states is still a felony.

D. Instruments for Past Consumption

As stated before, the reduced form models are estimated by including past prices in the demand equations instead of past consumption of alcohol and marijuana. The minimum legal purchasing age in the state in which the respondent lived at age 14 and the past crime per officer ratio are used as past prices for alcohol and marijuana, respectively. These variables are used because they are presumably independent of the individual specific "taste" effect and are less correlated with current price measures than other variables.[16]

V. Empirical Results

A. The Raw Data

Table 2 shows descriptive statistics of all the variables for the pooled sample used in this analysis.[17] Almost eighty percent (78.2%) of the pooled sample have used alcohol in the previous 30 days and just over twenty-five percent (25.4%) report currently using marijuana. Simple cross tabulations between alcohol and marijuana reveal that the current consumption of alcohol and marijuana in any given year are not independent. Table 3 shows the contemporaneous outcomes for use in 1984. The χ^2 statistic of 429.13 reveals that independence is strongly rejected. An individual who uses marijuana is much more likely to be using alcohol as well. The odds ratio statistic, calculated as the ratio of individuals who use marijuana conditioned on using alcohol to the number of individuals who use marijuana conditioned on

[16] Moore and Cook (1995) show that early environmental variables, in particular the purchasing age in which the respondent lived at age 14, do capture differences in previous alcohol consumption.

[17] Additional observations were lost because of missing data. The largest losses in observations came from missing alcohol and marijuana information (714 obs) and missing information regarding whether or not the respondent thought his/her father was an alcoholic (990 obs).

non-use of alcohol, is 5.0. Thus, an individual who uses alcohol is five times more likely to be currently using marijuana than an individual who does not use alcohol. The odds ratio, however, is not definitive in determining the structural relationship between these two drugs.

The gateway hypothesis states that adolescent involvement with drug use tends to follow a particular sequence. Drugs that are more prevalent in society, such as alcohol and tobacco, are used earlier in the sequence and become the "gateway" drugs through which an adolescent progresses into use of harder substances. The earlier one starts using these gateway drugs, the more likely one is to progress into use of harder drugs. Table 4 begins to examine the evidence supporting this theory by looking at the age at which youths and young adults in the NLSY began consuming alcohol, marijuana and cigarettes.[18] Cigarette consumption is generally started at a younger age than both alcohol and marijuana consumption. Although 5% of the population have started using alcohol and/or marijuana at the same age of 14, alcohol consumption is generally initiated before marijuana use for the larger population on average. Table 5 shows that 85% of youths and young adults in the NLSY consumed alcohol before they ever tried marijuana. Just over two percent of the population report initiating use of alcohol and marijuana at the same age. Only 12.7% of the youths and young adults used marijuana before using alcohol. It can be seen in the second panel of Table 5 that well over half of these individuals

[18] Results relying heavily on the reported age of first use of a drug should be accepted cautiously for at least three reasons. First, the question regarding age of first use of alcohol was asked in 1983 while others were asked in 1984. Some individuals who had not yet tried alcohol in 1983 may have by 1984, but this information would be missing. Second, questions regarding the age of first use will most likely be subject to recall error, especially if a significant amount of time has passed since the first experience with a specific drug. Third, there is a problem with interpretation of these questions. Although the alcohol questions clearly states it is inquiring about the age at which the individual regularly started using alcohol, which it defines as once or twice a month, the questions regarding age at which the individual started using cigarettes and marijuana are not as clear. The question regarding cigarette use was stated as the first time the individual "tried" a cigarette and the marijuana question was stated as the first time

who used marijuana before using alcohol used cigarettes before using marijuana.[19] Thus, most adolescents do not initiate drug use with marijuana.

B. Results from the Reduced Form Model

All the regressions that follow use pooled data from the 1983 and 1984 surveys. Information from earlier surveys were used to construct the past price variables. Table 6 provides the results from estimating the Adjusted Tobit model (4.1a - 4.1f) using a Full-Information Maximum Likelihood (FIML) technique.[20] The results for the key variables in this study are reported in the top portion of the table. Right away one notices the negative and significant effect of the beer tax variable in the alcohol prevalence and log quantity equations as well as the marijuana prevalence equation. Although the beer tax does not significantly influence the quantity of marijuana consumed, its significance in the prevalence equation indicates a contemporaneous complementarity between these two substances. Higher alcohol prices reduce the prevalence of both alcohol and marijuana consumption. Higher minimum legal purchasing ages, on the other hand, have no significant effect on the demand for either alcohol or marijuana once past consumption of alcohol is included.

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the individual "used" marijuana or hashish. These questions may be interpreted as either smoking a whole cigarette or joint, or just taking a puff. It is not clear how the individual's answers may be interpreted.

[19] Kandel and Yamaguchi (1993) found that 80.3% of high school seniors use alcohol before using marijuana and 15% use them at the same time, consistent with the findings above. They found that over 47% of high school seniors used alcohol before cigarettes and 24.9% used them at the same age. In addition, they found that alcohol was initiated first (mean age 12.5) then cigarettes (mean age 12.9) and then marijuana (14.6). These differences may be due to cohort effects, since their sample was taken in 1988. The NLSY sample is slightly older.

[20] Exclusion restrictions were determined from preliminary regressions. The demand equations were also estimated using a two-part model, which does not require any exclusion restriction nor does it make any assumptions regarding the structure of the error terms across equations. There are a few minor differences regarding the significance of price effects in the conditional demand equations across these two models, which will be noted. The full set of results from the two-part model are available from the author upon request.

The proxies for the price of marijuana also suggest a contemporaneous complementarity between alcohol and marijuana. Although lower monetary prices for marijuana, indicating by higher crime per officer ratios, only increase the prevalence of marijuana consumed, states that have decriminalized possession of marijuana have higher incidences of alcohol and marijuana consumption. The significance of the decriminalized state dummy variable in the marijuana prevalence equation is marginal, however, unlike that in the alcohol equation. The finding that individuals living in decriminalized states are significantly more likely to currently report using alcohol contradicts what has been found previously in the literature (Pacula, 1995 and forthcoming; Saffer and Chaloupka, 1995; Chaloupka and Laixuthai, 1994), but supports the finding of a complementary relationship between alcohol and marijuana. One possible explanation for the change in sign and significance of this variable in the alcohol demand equation may be the inclusion of the proxies for past consumption.[21]

The next three variables are proxies for the past consumption of alcohol, marijuana and cigarettes, respectively. Higher past prices of alcohol, indicated by a higher minimum legal purchasing age at age 14, have a negative and significant effect on the likelihood of using alcohol as well as the conditional quantity consumed, indicating state dependence with respect to alcohol consumption. This is consistent with what was found by Moore and Cook (1995). Higher past prices of alcohol are also associated with a lower likelihood of currently using marijuana, providing some evidence supporting the gateway hypothesis. The significance of this coefficient estimate, however, is only at the 10% level for a one-tailed test, so it is possible that the true

[21] When only the four youngest cohorts are examined, the decriminalized state has a negative and significant effect on the prevalence of alcohol, suggesting that there may be age-specific influences with respect to this variable.

parameter estimate is actually zero. Previous estimates using only the four youngest cohorts find no significant effect of higher past prices for alcohol on the current demand for marijuana (Pacula, 1995). Lower past marijuana prices, indicated by higher past crime per officer ratios, have a positive and significant effect on the current likelihood of using marijuana revealing that marijuana consumption by youths and young adults is also habit forming.[22] Past marijuana prices have no significant effect on the demand for alcohol, however. This, too, differs from results obtained with a restricted sample of only the four youngest cohorts. Lower past prices of marijuana have a positive and significant effect on the conditional quantity of alcohol consumed when the sample is restricted (Pacula, 1995). Finally, the significance of the past price of cigarettes in the current demand equations for alcohol and marijuana provides the strongest evidence of multi-commodity habit formation and a gateway effect. Individuals who were less likely to use cigarettes in the past because of higher past cigarette prices are significantly less likely to currently report using marijuana as well, indicating an intertemporal complementarity between cigarettes and marijuana. This finding differs substantially from the case of alcohol. Youths and young adults living individuals who lived in states with higher cigarette prices are more likely to report current use of alcohol, suggesting an intertemporal substitution effect.

Several other results merit mentioning. First, it is found that females are significantly less likely to be currently using alcohol and marijuana than men. Those women who do drink, drink significantly less than men, but those women who choose to smoke marijuana are not found to smoke significantly less than men. African-Americans report using less alcohol and consuming

[22] Estimates obtained from estimating a two-part model show that lower past prices for marijuana also significantly increase the quantity of marijuana currently consumed.

significantly less when they do drink than whites. However, African-Americans also report a marginally higher prevalence of marijuana use as well as higher conditional quantities consumed. Hispanics also report significantly lower prevalence rates than whites in the case of alcohol consumption, but there are no significant differences with respect to marijuana. Age has a nonlinear effect on alcohol consumption. Youths with higher abilities, as measured by a high score on the ASVAB test, are significantly more likely to report using alcohol in the past month and drink significantly more, and they report marginally lower levels of marijuana smoking. Youths and young adults living in urban areas are significantly more likely to currently report using both substances. Individuals raised by both parents are significantly less likely to currently use marijuana and smoke less on average. However, youths who were raised by working mothers are significantly more likely to report currently using both alcohol and marijuana. Having a father that is perceived to be an alcoholic by the respondent dramatically increases the likelihood of currently reporting the use of alcohol as well as the quantity consumed. It also significantly increases the likelihood that the youth currently uses marijuana. Parental education has a significant influence on the individual's decision to use both substances as does religious upbringing and interview conditions. Youths who are interviewed with a family member present are significantly less likely to report currently using alcohol and marijuana than those who have no one else present, while those youths with a friend present are significantly more likely to report use of both substances.

Although the demand functions were estimated in two steps, van de Ven and van Praag (1981) show that it is possible to back out the expected untransformed quantities of alcohol and marijuana consumed in the following manner:

$$E(A_{it}) = \Pr(A_{it}^* > 0) * E[\exp(\ln A_{it}) | A_{it}^* > 0] \tag{5.1a}$$
$$= \Phi(X_{it}\xi + \gamma_0 A_{it-1} + \eta_0 M_{it-1} + \rho_1\sigma_1) * \exp(X_{it}\beta + \bar{\gamma}A_{it-1} + \bar{\eta}_0 M_{it-1} + \sigma_1^2/2)$$

$$E(M_{it}) = \Pr(M_{it}^* > 0) * E[\exp(\ln M_{it}) | M_{it}^* > 0] \tag{5.1b}$$
$$= \Phi(W_{it}\delta + \gamma_1 A_{it-1} + \eta_1 M_{it-1} + \rho_2\sigma_2) * \exp(W_{it}\Gamma + \bar{\gamma}_1 A_{it-1} + \bar{\eta}_1 M_{it-1} + \sigma_2^2/2)$$

It, therefore, is possible to evaluate the impact of changes in prices on the unconditional quantities of these drugs consumed even though the unconditional demand equations are not directly estimated. The marginal price effects in the case of alcohol can be obtained as follows:

$$\frac{\partial E[A_t]}{\partial X_{jt}} = \hat{\beta}_j \exp(X_t\hat{\beta} + \hat{\gamma}_0 A_{t-1} + \hat{\eta}_0 M_{t-1} + 0.5\sigma_1^2) * \Phi\left(X_t\hat{\xi} + \hat{\bar{\gamma}} A_{t-1} + \hat{\bar{\eta}} M_{t-1} + \rho\sigma_1\right) \tag{5.2}$$
$$+ \hat{\xi}_j \phi(X_t\hat{\xi} + \hat{\bar{\gamma}} A_{t-1} + \hat{\bar{\eta}} M_{t-1}) * \exp(X_t\hat{\beta} + \hat{\gamma}_0 A_{t-1} + \hat{\eta}_0 M_{t-1} + 0.5\sigma_1^2)$$

for a change in the jth price. The marginal effects on the unconditional demands for alcohol and marijuana are recorded in the third and sixth columns of Table 6.[23] It is from these estimates that one can see that the beer tax has a clear negative effect on the unconditional quantities of both alcohol and marijuana. A one dollar increase in the tax on twenty-four 12-ounce cans of beer in 1984 would have reduced the quantity of alcohol consumed by 2.8 drinks. This represents a 15.2% reduction in the average quantity of alcohol consumed in 1984. This same increase in the beer tax would have been associated with a 14.5% reduction in marijuana consumption, with average marijuana smoking falling by .34 joints. Since consumption of both these substances is

[23]The marginal effects were calculated using each individual's exogenous variables instead of the average characteristics of the sample because of the nonlinearity of equation (5.2).

habit forming, these reductions in current consumption would have led to lower consumption levels in later periods as well.

Several important variables have been excluded from the analysis presented so far because of their potential endogeneity. The top portion of Table 7 shows what happens when family income is included in the analysis. The findings with respect to the impact of the current prices remain relatively unchanged. The beer tax is still negative and significant in the prevalence equations for both alcohol and marijuana and in the level of marijuana use. These coefficient estimates are also larger in magnitude when income is included. All the other price effects remain the same, although the significance of the past crime per officer ratio in the marijuana prevalence equation falls with the inclusion of family income. Family income has no significant effect on the demand for alcohol, but it has a negative and significant effect on the probability of using marijuana and a positive and significant effect on the conditional quantity consumed. The effect on quantity consumed is small, however, and outweighed by the impact on prevalence, making the overall marginal effect on consumption negative.

When education, living arrangements, marital status, and other potentially endogenous variables are included the key finding regarding contemporaneous complementarity and single-commodity habit formation again remain unchanged. The beer tax variable remains robust although the coefficient estimates do decrease in magnitude. Prior use of alcohol, as indicated with a low MPA at age 14, continues to significantly increase the likelihood of currently using alcohol as well as the conditional quantity consumed. It also continues to marginally increase the current likelihood of using marijuana. None of the findings with respect to the past price of

marijuana or the past price of cigarettes change, although the current crime per officer ratio has a negative and marginally significant effect on the probability of currently using alcohol. Since higher crime per officer ratios indicate a lower monetary price of marijuana, this would suggest a contemporaneous substitution effect. Analysis of the marginal effects reported in the last column reveal that this substitution effect is smaller in magnitude than the complementary relationship implied by the beer tax variable.

With the inclusion of these additional endogenous variables, income becomes positive and significant in the alcohol prevalence equation and loses its significance in the marijuana conditional quantity equation. More educated individuals are significantly less likely to report using large quantities of alcohol and have a lower likelihood of reporting current use of marijuana. Youths and young adults enrolled in school report significantly lower prevalence rates for alcohol as well as lower quantities consumed. Likewise, current students report marginally lower quantities of marijuana consumed. Individuals who report currently living with their parents are significantly less likely to report using alcohol and marijuana. Those who do report using these substances and are living with their parents report lower alcohol consumption levels but higher levels of marijuana use. A similar pattern is found among those who are currently married. Those individuals that have been previously stopped by the police under suspicion of an illegal act are significantly more likely to be using both substances, although they do report significantly lower levels of marijuana use.

VI. Conclusions

Overall, the findings presented here generally support a theory of multi-commodity habit formation and the gateway hypothesis since previous consumption of alcohol and cigarettes do increase the current likelihood of using marijuana. Previous use of marijuana, however, does not appear to have any significant effect on the demand for alcohol, so the reinforcement effects do not appear to be symmetric. Symmetry is something that can only be tested by estimating a structural model, however. It is also possible that the rates of depreciation of specific drugs differ so that reinforcement across some drugs over time is negligable.

Both substances demonstrate commodity-specific state-dependence. Further, all the specifications of the model show a strong contemporaneous complementarity between the demands for alcohol and marijuana. These two findings together suggest that public policies which increase the price of alcohol will be effective at reducing the quantity of marijuana consumed by youths and young adults in the short run as well as in the long run. Estimates from the reduced form demand equations reveal that marijuana consumption is just as sensitive to changes in the price of alcohol as alcohol consumption. A one dollar increase in 1984 would have reduced alcohol consumption among youths and young adults anywhere from 11.3 % to 15.9% and would have reduced marijuana consumption by 11.8% to 15.3%.

An important implication of this study is that current estimates of the optimal tax on alcohol and cigarettes may be underestimated because they ignore the intertemporal relationship between these substances and marijuana, an illicit substance. It is also possible that similar intertemporal relationships exist between these substances and other illicit drugs. The optimal tax on alcohol and cigarettes should incorporate the marginal cost of the externalities generated by these

potential drug users. Before such an estimate may be considered, however, one must first identify the contemporaneous and intertemporal relationships that exist across drugs and then quantify the external cost imposed by potential users. This paper takes an important first step in that direction by examining the contemporaneous and intertemporal relationship between alcohol and marijuana use.

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Table 1
Comparative Statics for Model Two
Impact of an Increase in the Price of Alcohol in Period 1

Initial Conditions	Current Consumption	Net Substitutes	Net Complements
$A_0 > 0$ $M_0 = 0$	$A_1^* > 0$ $M_1^* > 0$	A_1^* decreases M_1^* increases A_2^* ? M_2^* ?	A_1^* decreases M_1^* decreases Prob($A_2^* > 0$) decreases Prob($M_2^* > 0$) decreases
	$A_1^* > 0$ $M_1^* = 0$	A_1^* decreases Prob($M_1^* > 0$) increases Prob($A_2^* > 0$) decreases Prob($M_2^* > 0$) decreases	A_1^* decreases Prob($M_1^* > 0$) decreases Prob($A_2^* > 0$) decreases Prob($M_2^* > 0$) decreases
$A_0 > 0$ $M_0 > 0$	$A_1^{**} > 0$ $M_1^{**} > 0$	A_1^{**} decreases M_1^{**} increases A_2^{**} ? M_2^{**} ?	A_1^{**} decreases M_1^{**} decreases Prob($A_2^{**} > 0$) decreases Prob($M_2^{**} > 0$) decreases
	$A_1^{**} > 0$ $M_1^{**} = 0$	A_1^{**} decreases Prob($M_1^{**} > 0$) increases Prob($A_2^{**} > 0$) decreases Prob($M_2^{**} > 0$) decreases	A_1^{**} decreases Prob($M_1^{**} > 0$) decreases Prob($A_2^{**} > 0$) decreases Prob($M_2^{**} > 0$) decreases

Table 2
Descriptive Statistics

Variables	Description	Mean	Std Dev
Drugs:			
Alc30 (t)	thirty-day prevalence of alcohol	0.782	0.413
Drinks (t)	total number of drinks youth consumed in previous 30 days	18.458	33.443
Log (drinks) (t)	natural log of the total number of drinks consumed in the previous 30 days	2.134	1.541
Mari30 (t)	thirty-day prevalence of marijuana	0.254	0.435
Times used MJ (t)	total number of times youth used marijuana in past 30 days	2.239	5.906
Log (marijuana) (t)	natural log of the total number of times youth used marijuana in the previous 30 days.	1.295	1.182
Prices:			
Beer tax (t)	real state and federal tax on 24 twelve ounce cans of beer	0.524	0.556
Minimum purchase age (t)	minimum legal purchase age for beer in the state in which the youth resides	19.612	1.089
Decriminalized state (t)	DV=1 if youth lives in a decriminalized state	0.317	0.465
Crime per officer ratio (t)	ratio of common crime to number of officers at the SMSA levels.	14.807	9.420
Missing crime per officer ratio (t)	missing crime per officer ratio	0.311	0.463
MLPA at age 14	minimum legal purchase age in the state in which youth resided in at age 14	19.151	1.413
Past price of cigarettes (t)	real price of cigarettes, inclusive of tax, in the previous year	87.826	8.622
Past crime per officer ratio (t)	crime per officer ratio in previous year	17.136	17.344
Personal Characteristics:			
Female	DV=1 if youth is female	0.533	0.499
Black	DV=1 if youth is African-American	0.252	0.434
Hispanic	DV=1 if youth is Hispanic	0.148	0.355
Age (t)	age of youth	22.072	2.312
Age squared (t)	age of youth squared	492.522	102.585
Log(weight) (t)	natural logarithm of youth's rate	4.989	0.203
ASVAB	Sum of ave. score on 3 mathematics and 2 verbal sections of ASVAB vocational test	36.448	12.448
Urban (t)	DV=1 if youth lives in urban area	0.768	0.422
Family Characteristics:			
Lived with both parents	DV=1 if youth lived with both parents at age 14	0.687	0.464
Mother worked	DV=1 if youth's mother worked when youth was 14	0.522	0.500
Catholic	DV=1 if raised Catholic	0.324	0.468
Protestant	DV=1 if raised Protestant	0.228	0.420
Atheist	DV=1 if raised atheist	0.041	0.198
Other	DV=1 if raised in other religion	0.113	0.317
Number of siblings	number of siblings in 1979	3.786	2.592
Alcoholic father	DV=1 if youth reports having an alcoholic father	0.211	0.408
Income Measures:			
Mom HS degree	DV=1 if mother finished high school	0.536	0.499
Mom college degree	DV=1 if mother finished college	0.069	0.254
Dad HS degree	DV=1 if father finished high school	0.491	0.500
Dad college degree	DV=1 if father finished college	0.117	0.321
Missing father's education	DV=1 if father's education is missing	0.127	0.333
Missing mother's education	DV=1 if mother's education is missing	0.057	0.231
Income (t)	total household income (in thousands of dollars)	19.374	15.675
Potentially Endogenous Variables:			
Education (t)	number of years of schooling completed	12.295	1.998
In school (t)	DV=1 if youth is currently enrolled in school	0.193	0.395
Ever been stopped by the police	DV=1 if youth was ever stoped y the police (1980 survey)	0.183	0.387
Living with parents (t)	DV=1 if youth currently lives with both parents	0.413	0.492
Marry (t)	DV=1 if youth is currently married	0.293	0.455
Interview Factors:			
Family present during interview (t	DV=1 if youth had family present during the interview	0.170	0.376
Friend present during interview (t	DV=1 if youth had friend present during the interview	0.023	0.150
Other present during interview (t)	DV=1 if youth had someone else present during the interview	0.029	0.168
Year83	DV=1 if data is from 1983	0.500	0.500

Table 3
Thirty-Day Prevalence - 1984
Frequencies

Frequency Percent of Pop. (Percent of Row) [Percent of Column]	Marijuana - no	Marijuana - yes	Totals
Alcohol - no	2090 29.65 (94.70) [37.01]	117 1.66 (5.30) [8.35]	2207 31.3 (100.0)
Alcohol - yes	3557 50.46 (73.46) [62.99]	1285 18.23 (26.54) [91.65]	4842 68.69 (100.0)
Totals	5647 80.11	1402 19.89	7049 100.0

Table 4
Average Age of First Use

Percent of Population:	5%	10%	15%	20%	25%	50%	75%
Alcohol	14	15	16	16	16	18	19
Marijuana	14	16	18	25	-	-	-
Cigarettes	8	10	10	11	12	14	18

Table 5
Evidence Regarding the Gateway Effect

Drug A	Drug B	% A before B	% B before A	% Same Age
Alcohol	marijuana	83.5	12.7	3.7
Alcohol	cigarettes	17.9	75.4	6.7
Cigarettes	marijuana	94.0	2.9	3.1
If MJ before Alc: Cigarettes	marijuana	66.7	16.1	17.2
If Cig before Alc: Cigarettes	marijuana	96.5	0.9	2.6

Table 6
Reduced Form FIML Model
Pooled Data (t=1983, 1984)

Variable	FIML Prob(A>0) Coefficient	Std Error	FIML Log(Alcohol) Coefficient	Std Error	Marginal Effects on Uncondit. Demand	FIML Prob(M>0) Coefficient	Std Error	FIML Log(Marijuana) Coefficient	Std Error	Marginal Effects on Uncondit. Demand
Beer tax (t)	-0.063 **	0.026	-0.115 ***	0.038	-2.818	-0.071 ***	0.027	0.006	0.049	-0.324
Minimum Purchase Age (t)	0.002	0.014	0.008	0.019	0.204	0.006	0.013	-0.009	0.022	0.009
Crime per officer (t)	-8.43E-04	1.43E-03	1.43E-03	1.84E-03	0.034	1.75E-03 a	1.25E-03	-3.79E-04	2.07E-03	0.008
Decriminalized state (t)	0.114 ***	0.028	0.022	0.038	0.596	0.041 a	0.027	0.027	0.048	0.257
MPA at age 14	-0.020 **	0.010	-0.027 *	0.014	-0.663	-0.015 a	0.010	0.000	0.017	-0.073
Past crime per officer (t)	-7.22E-04	7.05E-04	6.55E-04	9.17E-04	0.015	1.14E-03 *	6.25E-04	-6.73E-04	1.03E-03	0.004
No price for marijuana (t)	-0.012	0.032	-0.011	0.038	-0.273	-0.017	0.033	0.013	0.048	-0.053
Past price of cigarettes (t)	0.006 ***	0.002	0.001	0.003	0.032	-0.006 ***	0.002	0.003	0.004	-0.021
Female	-0.359 ***	0.025	-0.514 ***	0.040	-12.674	-0.207 ***	0.024	0.062	0.066	-0.850
Black	-0.163 ***	0.032	-0.201 ***	0.047	-4.967	0.048 a	0.034	0.104 *	0.059	0.470
Hispanic	-0.249 ***	0.042	-0.034	0.055	-0.979	0.017	0.039	0.024	0.066	0.135
Age (t)	0.135 a	0.100	-0.229 a	0.140	-5.478	0.116	0.101	-0.166	0.177	0.180
Age squared (t)	-0.003	0.002	0.005 *	0.003	0.125	-0.003	0.002	0.004	0.004	-0.004
ASVAB	0.004 ***	0.001	0.012 ***	0.002	0.303	0.001	0.001	-0.003 a	0.002	-0.003
Urban (t)	0.130 ***	0.032			0.823	0.097 ***	0.035			-0.197
Log(weight) (t)			0.034	0.087	0.079			-0.086	0.115	0.467
Parents	-0.008	0.026	-0.012	0.037	-0.295	-0.047 *	0.026	-0.125 ***	0.046	-0.511
Momwork	0.052 ***	0.024	0.029	0.034	0.738	0.034 a	0.024	-0.038	0.042	0.075
Fathalc	0.104 ***	0.030	0.168 ***	0.041	4.146	0.159 ***	0.029	-0.067	0.060	0.610
Mother finished high school	0.080 ***	0.029	0.173 ***	0.040	4.245	0.093 ***	0.029	-0.070 a	0.054	0.284
Mother finished college	-0.056	0.052	-0.050	0.072	-1.255	0.021	0.051	-0.081	0.088	-0.086
Father finished high school	0.033	0.031	0.076 *	0.042	1.856	0.011	0.030	-0.024	0.050	-0.003
Father finished college	0.007	0.044	0.005	0.061	0.114	-0.006	0.042	-0.034	0.073	-0.106
Raised Catholic	0.248 ***	0.040	0.123 **	0.054	3.129	0.012	0.038	-0.045	0.065	-0.044
Raised Protestant	0.097 ***	0.036	0.060	0.050	1.501	-0.064 *	0.036	0.111 *	0.066	-0.054
Raised Atheist	0.095 a	0.064	0.177 **	0.089	4.359	0.101 *	0.060	0.049	0.104	0.600
Raised in other religion	-0.046	0.041	-0.028	0.060	-0.709	-0.007	0.043	-0.009	0.073	-0.054
Number of siblings	-0.013 ***	0.005	-0.002	0.007	0.054	-0.004	0.005	0.005	0.008	-0.007
Family member present (t)	-0.079 **	0.033	-0.038	0.044	0.976	-0.054 *	0.031	0.099 *	0.056	-0.032
Friend present (t)	0.252 ***	0.085	0.096	0.104	2.476	0.241 ***	0.072	-0.090	0.127	0.951
Someone else present (t)	-0.036	0.069	-0.068	0.097	-1.673	0.012	0.069	-0.073	0.119	-0.112
Year 1983 dummy	0.688 ***	0.033	-0.145 ***	0.050	-3.100	0.298 ***	0.032	-0.533 ***	0.093	0.211
Missing father's education	0.007	0.040	-0.078	0.055	-1.894	0.005	0.039	-0.049	0.069	-0.088
Missing mother's education	0.065	0.055	0.217 ***	0.076	5.294	0.100 *	0.054	-0.099	0.096	0.256
Constant	-1.449	1.164	3.936 **	1.660	94.512	-1.544 a	1.159	5.595 ***	2.169	5.391
Rho			1.7844 ***	0.024				1.3758 ***	0.18238	
Sigma			0.84592 ***	0.018				-0.72956 ***	0.12936	
Pseudo R-squared	0.417					0.370				
Observations	14,098					14,098				
Log Likelihood	-26,665.79					-13,084.92				

Notes: (1) Omitted categories are as follows: male, white, parents completed the 8th grade, religion=Baptist, and no one present during interview.

(2) Significance is indicated by the following:

*** Significance at the 1% level (two-tailed test)

** Significance at the 5% level (two-tailed test)

* Significance at the 10% level (two-tailed test)

a Significance at the 10% level (one-tailed test)

Table 7
Reduced Form FIML Model
Potentially Endogenous Variables Included
Pooled Data (t = 1983, 1994)

	Alcohol Equations					Marijuana Equations				
	FIML				Marginal Effects on Uncondit. Demand	FIML				Marginal Effects on Uncondit. Demand
	Prob (A> 0)		Log(Drinks)			Prob (M> 0)		Log(Marijuana)		
Variable	Coefficient	Std. Error	Coefficient	Std. Error		Coefficient	Std. Error	Coefficient	Std. Error	
Short Form Model + Income										
Beer tax (t)	-0.066 **	0.026	-0.120 ***	0.038	-2.941	-0.074 **	0.027	0.002	0.049	-0.342
Minimum Purchase Age (t)	-1.80E-04	0.014	0.008	0.019	0.188	0.005	0.013	-0.010	0.022	-0.001
Crime per officer (t)	-0.001	0.001	0.001	0.002	0.028	1.79E-03 [a]	1.27E-03	-4.08E-04	2.06E-03	0.007
Decriminalized state (t)	0.115 ***	0.028	0.025	0.038	0.669	0.037 [a]	0.027	0.027	0.047	0.232
MPA at age 14	-0.020 *	0.010	-0.028 **	0.014	-0.685	-0.015 [a]	0.010	0.000	0.017	-0.070
Past crime per officer (t)	-4.10E-05	6.86E-04	9.11E-04	9.23E-04	0.022	1.22E-03 [a]	6.23E-04	-5.92E-04	1.02E-03	0.004
No price for marijuana (t)	-0.015	0.032	-0.014	0.038	-0.341	-0.026	0.033	0.011	0.049	-0.096
Past price of cigarettes (t)	5.86E-03 ***	1.94E-03	4.46E-04	2.74E-03	0.014	-5.45E-03 ***	1.95E-03	2.45E-03	3.59E-03	-0.020
Family income (t)	3.78E-04	8.74E-04	-4.53E-04	1.09E-03	-0.011	-2.71E-03 ***	7.78E-04	6.21E-05 **	1.49E-03	-0.013
Pseudo- R squared	0.417					0.371				
Log Likelihood	-26,665.80					-13,077.48				
Long Form Model										
Beer tax (t)	-0.048 *	0.027	-0.090 **	0.037	-2.092	-0.052 **	0.027	0.011	0.052	-0.264
Minimum Purchase Age (t)	-3.32E-04	0.014	0.004	0.019	0.093	0.003	0.013	-0.014	0.025	-0.012
Crime per officer (t)	-1.83E-03 [a]	1.36E-03	3.78E-05	1.74E-03	-3.20E-04	1.45E-03	1.28E-03	-0.002	0.002	0.004
Decriminalized state (t)	0.108 ***	0.028	0.011	0.037	0.313	3.05E-02	2.66E-02	-0.031	0.052	0.104
MPA at age 14	-0.016 [a]	0.010	-0.026 *	0.014	-0.603	-0.013 [a]	0.010	0.005	0.018	-0.061
Past crime per officer (t)	2.29E-04	0.001	0.001	0.001	0.020	1.20E-03 **	6.05E-04	-0.001	0.001	0.004
No price for marijuana (t)	0.018	0.032	0.018	0.037	0.423	-4.84E-02 [a]	2.98E-02	0.053	0.051	-0.155
Past price of cigarettes (t)	0.006 ***	0.002	-0.001	0.003	-0.002	-5.47E-03 ***	1.91E-03	5.39E-03 [a]	3.71E-03	-0.019
Family income (t)	1.67E-03 *	9.08E-04	4.60E-04	1.10E-03	0.012	-1.79E-03 **	7.93E-04	-1.35E-04	1.53E-03	-0.010
Education (t)	0.004	0.008	-0.017 [a]	0.011	-0.385	-0.033 ***	0.008	0.011	0.015	-0.160
In school (t)	-0.074 **	0.033	-0.259 ***	0.044	-5.963	-0.019	0.031	-0.096 [a]	0.059	-0.303
Live with parents (t)	-0.162 ***	0.031	-0.119 ***	0.039	-2.827	-0.096 ***	0.028	0.123 **	0.054	-0.271
Married (t)	-0.396 ***	0.031	-0.380 ***	0.043	-8.926	-0.179 ***	0.030	0.283 ***	0.060	-0.399
Stopped by Police (1980)	0.174 ***	0.035	0.210 ***	0.042	4.898	0.187 ***	0.029	-0.136 **	0.057	0.746
Pseudo- R squared	0.431					0.410				
Log Likelihood	-26,539.35		-26,539.35			-13,017.27		-13,017.27		

Notes: (1) Additional regressors include those variables in Table 6.

(2) Significance is indicated by the following:

*** Significance at the 1% level (two-tailed test)

** Significance at the 5% level (two-tailed test)

* Significance at the 10% level (two-tailed test)

[a] Significance at the 10% level (one-tailed test)