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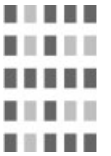

Alcohol and marijuana use among college students: economic complements or substitutes?

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Summary

Previous research has shown that the recent tightening of college alcohol policies has been effective at reducing college students' drinking. Over the period in which these stricter alcohol policies have been put in place, marijuana use among college students has increased. This raises the question of whether current policies aimed at reducing alcohol consumption are inadvertently encouraging marijuana use. This paper begins to address this question by investigating the relationship between the demands for alcohol and marijuana for college students using data from the 1993, 1997 and 1999 waves of the Harvard School of Public Health's College Alcohol Study (CAS). We find that alcohol and marijuana are economic complements and that policies that increase the full price of alcohol decrease participation in marijuana use. Copyright © 2004 John Wiley & Sons, Ltd.

Keywords demand; marijuana; alcohol; economic complements

Introduction

Prevalence statistics from population surveys consistently show that substance use and abuse among college students is higher than estimates from the general population. For example, the 1999 Monitoring the Future Survey (MTF) reports annual prevalence rates for alcohol, marijuana and any illicit drug use among college students to be 83.6, 35.2 and 36.9%, respectively [1]. By comparison, the 1999 National Household Survey on Drug Abuse (NHSDA) reports prevalence rates for young adults aged 19–28 of 84.1% for alcohol use, and 27.6, and 30.3%, respectively for marijuana and any illicit drug use [2]. The higher use rates among college samples are particularly disturbing because they are frequently accompanied by serious health consequences, acts of violence and/or crime, poor performance in school, and other negative outcomes [3,4].

In an effort to reduce substance use and abuse among college students, Congress passed the Drug-Free Schools and Communities Act of 1986, which set aside funds for substance abuse prevention programs in higher education. Nontheless, the first survey on drinking and illicit drug use on college campuses, the 1993 College Alcohol Study (CAS), found that 84% of college students had used alcohol in the past year [4] and that one in four (24.8%) students had used marijuana in the past year [5]. As media attention on alcohol-related tragedies occurring on college campuses

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heightened, a new wave of private and public initiatives aimed at curbing underage and youthful drinking began. These initiatives included the campaigns of the National Association of State Universities and Land Grant Colleges, the Robert Wood Johnson Foundation's Matter of Degree program, and the US Department of Education Fund for Improvement of Secondary Education Programs [6]. In addition, numerous states and localities began passing tighter alcohol control policies specifically targeting alcohol use and abuse among minors.

Recent research shows that some of these state and local policies have been effective at reducing alcohol use and abuse among college students. In particular, higher beer taxes, tougher drunk driving laws, state restrictions on happy hour pricing and restrictions on social access have all been associated with reduced drinking and/or binge drinking among college students [7,8]. In addition, some campus policies, such as total bans on drinking on campus, have been associated with an increased level of abstinence from alcohol use and lower levels of heavy episodic drinking among college students [9]. At the same time, however, marijuana use among college students has been on the rise. Trend data from the 1993 and 1999 CAS show an increase in 30-day prevalence rates of marijuana use of 21.7% (a 2.8 percentage point increase) from 1993 to 1999 [10]. Data from the Monitoring the Future Survey (MTF) show a rise in 30-day prevalence rates of marijuana use among college students one to four years beyond high school of 46.0% (a 6.5 percentage point increase) from 1993 to 1999.

The rise in marijuana use during a period in which tougher alcohol policies have been enacted raises the question as to whether these alcohol policies have had the unintended consequence of raising illicit drug use among the college population. If alcohol and marijuana are economic substitutes for college students then these policies may not have the overall effect desired. However, it may be the case that the recent rise in college students' marijuana use merely reflects a broader societal trend that is independent of the policies being enacted. Evidence supporting this alternative hypothesis comes from data showing that prevalence rates for other illicit drugs (excluding marijuana) also rose during the same time period [10].

This paper begins to explore whether recent alcohol restrictions have increased the use of marijuana by examining the economic relationship between the demands for alcohol and marijuana among college students. Previous studies examining the issue of complementarity and substitutability between alcohol and marijuana are inconclusive and do not explicitly address the relationship between these two substances in this key population. We begin by examining own- and cross-price effects in annual and 30-day prevalence equations for alcohol and marijuana for all students. Additional policy variables capturing the non-monetary components of price, such as accessibility and the legal environment for using each substance, are also examined. We find evidence that alcohol and marijuana are economic complements. Specifically, we find that increasing the monetary costs of marijuana use decreases participation in both marijuana and alcohol use. Also, policies that reduce access to alcohol, such as banning alcohol consumption on campus or state laws restricting happy hours, reduce both alcohol and marijuana use.

We then examine whether differences exist in the relationship between these two substances by gender and age. Although we find that alcohol use by males and females respond differently to campus alcohol bans, both males and females are less likely to use marijuana on campuses where alcohol consumption has been banned. We find no difference in the impact of policy variables on marijuana or alcohol use across individuals less than 21 compared to those of legal drinking age.

The rest of this paper is organized as follows. In the following section we review the literature on the relationship between alcohol and marijuana use. Then we present the statistical model on which our empirical work is based. Next, the data used in this study, and the results are described. Finally we conclude with a discussion of our findings.

Literature review

During the past decade a growing economic literature has emerged investigating the contemporaneous relationship between the demands for alcohol and marijuana in the general and youth populations. Initial studies evaluating the relationship between demands in youth and young adult populations concluded that alcohol and marijuana were economic substitutes [11,12]. Subsequent articles that have attempted to include additional proxies for the price of marijuana or that have

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examined more recent cohorts have generally found evidence of complementarity between alcohol and marijuana use, although the finding is often limited to specific populations [13–16]. The main exception has been a recent study conducted on household data from Australia [17].

Although their paper was not published until 2001, DiNardo and Lemieux [12,18] were the first to examine the relationship between demands for alcohol and marijuana. Using state-aggregated data on high school seniors from 1980 through 1989 from the Monitoring the Future Surveys, prevalence equations for alcohol and marijuana that included the price of alcohol, the minimum legal drinking age, and marijuana decriminalization were estimated. The authors found that marijuana decriminalization had a significant and negative effect on the prevalence of alcohol use by high school seniors although it had no significant effect on marijuana use. In addition, they found that higher minimum legal drinking ages were associated with higher marijuana use. They concluded from these two findings that alcohol and marijuana are economic substitutes for youth.

Using micro-level data on drinking behavior among high school seniors from the 1982 and 1989 Monitoring the Future Surveys, Chaloupka and Laixuthai [11] confirmed DiNardo and Lemieux's [12] earlier finding. They estimated models for both the frequency of drinking as well as the probability of heavy drinking and found that both were negatively related to beer prices and state decriminalization status, again suggesting that alcohol and marijuana are economic substitutes among youth. Separate analyses of the 1989 data included measures of the wholesale or retail price of commercial grade or sinsemilla marijuana from the DEA for 19 cities, thus reducing the influence of omitted variable bias in these results. They found in the majority of the 1989 specifications that a positive relationship existed between drinking frequency and marijuana price as well as binge drinking and marijuana price, which they interpreted as evidence of a substitution effect.

Thies and Register [16] were the first to use individual level data to estimate demand equations for both alcohol and marijuana use. Using data from the 1984 and 1988 National Longitudinal Survey of Youth, they estimated logit and Tobit specifications for alcohol (use in the past 30 days and frequency of binge drinking in the past 30 days), marijuana, and cocaine use that included measures of marijuana's decriminalization status and the minimum legal purchasing age. No measure of either the monetary price of alcohol or marijuana was included in any of their models. For models estimated over the 1984 sample, the authors found that decriminalization of marijuana use increased the likelihood of alcohol (any use in the past 30 days) and cocaine use but had no significant effect on marijuana use. However, these findings became insignificant when estimation was carried out over the 1988 sample in all cases except the binge drinking equation, where decriminalization was found to have a negative effect. Their Tobit specifications of the quantities consumed of each of these substances did not provide any additional insights, and thus the authors concluded that there is insufficient evidence to infer that alcohol and marijuana are substitutes.

Pacula [15] extended the analysis conducted by Thies and Register [12] by estimating the conditional and unconditional demands for alcohol and marijuana using the 1984 National Longitudinal Survey of Youth using specifications that included measures of the full price of both substances. She found 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, providing the first evidence of a complementary relationship between alcohol and marijuana. Although Paula found that state decriminalization status was associated with higher levels of alcohol use, she also found that it was negatively associated with marijuana use, raising some doubt regarding how to interpret this variable in both equations.

Saffer and Chaloupka [14] conducted the most comprehensive analysis of cross-price effects to date. Using data from the 1988, 1990 and 1991 waves of the NHSDA they estimated annual prevalence equations for marijuana, cocaine and heroin participation in addition to a continuous measure of the number of days alcohol was used in the past month for specific ethnic, gender and age subgroups. County-level alcohol prices and state-level marijuana decriminalization laws were used as measures of the full price for alcohol and marijuana use, respectively. State-level prices for cocaine and heroin were also included in all of their specifications so as to control for any relationship alcohol and marijuana demands have with cocaine and heroin. They find strong evidence of complementarity between alcohol and marijuana for the full sample, white (non-Hispanic) males and African-Americans. However, for two

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subgroups, Native Americans and Hispanics, the data show that alcohol and marijuana are economic substitutes. They find no significant cross-price effects for Asians, women or youth. The variation in the relationship between demands across different ethnic, gender and age groups is important in light of the fact that it is often ignored when general policies are being considered.

Exploring the differential relationship between demands across different age groups, Farrelly *et al.* [13] use data from the 1990–1996 NHSDA to estimate probit specifications of marijuana use in the past 30 days for youth (aged 12–20) and young adults (aged 21–30) separately. Average state-level beer prices were constructed from the American Chamber of Commerce Research Association's city-specific quarterly price data and merged with the data to capture movements in the price of alcohol. State fixed effects were also included to control for unobserved factors that might be correlated with price and/or consumption. The price of beer was only found to have a negative and significant effect on marijuana participation for youths (aged 12–20), suggesting a complementary relationship between alcohol and marijuana for this age group. No significant cross-price effects were found to exist for the young adult sample.

Cameron and Williams [17] provided the first international estimates of the cross-price effects between alcohol and marijuana. Using Australian data from the 1988, 1991, 1993, and 1995 National Drug Strategy Household Surveys, Cameron and Williams took advantage of state-level variation in marijuana prices and criminal status of marijuana to estimate past year participation equations for alcohol, marijuana and cigarettes. Their findings of a positive and significant effect of the price of alcohol in the marijuana use equation suggest that marijuana and alcohol are economic substitutes for Australians. Separate analyses were not done by subgroups, however, to determine if this finding is consistent across different ethnic, gender and age groups in the population.

The recent evidence showing differential relationships between alcohol and marijuana use by age groups suggests that a separate analysis of college students could be particularly useful in light of the policies targeting this specific population. In addition, there are a number of factors that put college students at greater risk than other young adults at developing illicit drug use behaviors, including absence of parental controls and oversight, the tendency of college students to try new, previously prohibited behaviors, and the economic ability to afford illicit drugs [10]. These factors suggest that a careful analysis of the relationship between the demands for these two drugs among college students is needed. This paper begins to fill this void by examining the relationship between the demands for alcohol and marijuana, focusing our analysis on own- and cross-price effects, for the full population and for important demographic groups (males, females, minors and those of legal drinking status). We include additional measures of price and availability of marijuana that are frequently ignored in the previous literature. In addition we control for unobserved school and state specific effects so that we can correctly attribute associations to the policies themselves.

The model

The decision to use alcohol and/or marijuana among college students can be described by the latent variable model:

$$A_{ij}^{*} = X_{ij}\beta + P_j\phi + \varepsilon_{ij} \tag{1}$$

$$M_{ij}^{*} = X_{ij}\alpha + P_j\kappa + \mu_{ij} \tag{2}$$

where A_{ij}^{*} and M_{ij}^{*} are underlying continuous measures of the latent demand for alcohol and marijuana respectively, of the ith individual residing in community j. These latent measures of demand are derived from the standard utility-maximizing framework. X_{ij} represents individual (i) and community-level (j) factors that are related to the marginal benefit and marginal cost of using alcohol and/or marijuana, such as the individual's gender, age, religious upbringing, and characteristics of the college that the student attends. P_j represents a vector of prices an individual living in community j faces for alcohol and marijuana and is intended to represent both the monetary and non-monetary components of price, such as the expected legal sanctions associated with using these substances, and social access. The unobserved components of latent demand for alcohol and marijuana, ε_{ij} and μ_{ij}, are assumed to be correlated such that $\text{corr}(\varepsilon_{ij}, \mu_{ij}) = \rho$.

We do not observe the latent demand for alcohol or marijuana, only whether or not the student decides to use each of these substances. The observability criteria for alcohol and

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marijuana use can be written as follows:

$$A_{ij} = 1\ (A_{ij}^{*} > 0) \tag{3}$$

$$M_{ij} = 1\ (M_{ij}^{*} > 0) \tag{4}$$

Here, A_{ij} and M_{ij} are dichotomous indicators that are set equal to one when the person is observed to be using alcohol or marijuana respectively. Assuming that ε_{ij} and μ_{ij} have a standard normal bivariate distribution, we can estimate this bivariate probit model using maximum likelihood.

Before these models can be estimated, there remains an outstanding statistical issue arising from our use of multilevel data that must be addressed. In addition to using individual level data from the college students, we employ information on the monetary and non-monetary components of the price of marijuana and alcohol that are measured at both the college (P_c) and the state levels (P_s). For example, in the case of alcohol, we have measures of social access at both the college level (alcohol consumption banned on campus, availability of on-campus housing prohibiting use of alcohol, number of bars within a mile of campus) and the state level (restrictions on happy hours and low price sales, and open container laws). At each of these levels, there may be additional unobserved variables impacting social access that remain unaccounted for. These common unobservables induce a correlation among the error terms of individuals coming from the same school and/or state 'cluster'.

The state level unobserved component of the error terms is particularly problematic as unobserved state factors are likely to be highly correlated with our included state level policy variables. For example, a key component of the full cost of marijuana use is the expected cost of legal penalties associated with using the drug, which we capture through a variable representing the maximum fine associated with possession of an ounce of marijuana for each state. However, the expected cost of legal sanctions is determined by both the penalties imposed in the event of being apprehended and the probability of being apprehended. If states with harsher penalties are less likely to enforce the laws, then the *expected* penalty may be lower in states with higher penalties. As we have no measure of enforcement, its effect is accounted for in the error term. This is problematic if the unobserved enforcement is correlated with our measure of legal penalties, because our estimates will suffer omitted variable bias. Similarly, state attitudes about drinking are likely to be correlated with the state beer tax, our measure of the monetary price of alcohol. Depending on the nature of this correlation, estimates of own- and cross-price effects may be biased upward or downward. To ameliorate the potential bias caused by these omitted variables, we include state identifiers in our specification of the empirical model.

The correlation in error terms among individuals attending the same college is due in large part to the sampling methodology employed in the survey, discussed below. Given that we have no *a priori* assumptions regarding the correct specification of the variance–covariance matrix within college clusters and how it could relate to omitted measures of price, we use the general robust cluster adjustment of standard errors within school clusters to correct for this unobserved correlation. The empirical model estimated, therefore, is given by

$$A_{ij}^{*} = X_{ij}\beta + P_c\phi_1 + P_s\phi_2 + S_s\pi + \varepsilon_{ij} \tag{5}$$

$$M_{ij}^{*} = X_{ij}\alpha + P_c\kappa_1 + P_s\kappa_2 + S_s\lambda + \mu_{ij} \tag{6}$$

$$(\varepsilon_{ij}, \mu_{ij}) \sim \text{bivariate normal}\ (0, 0, 1, 1, \rho) \tag{7}$$

and by the observability rules given in (3) and (4) above, and where S_s is a vector of state indicators, P_c and P_s represent components of the full price of alcohol and marijuana use measured at the college and state levels, respectively. Standard errors are adjusted for clustering at the college level using the cluster option in STATA version 7.0.

Data

The Harvard School of Public Health College Alcohol Study

We pool information on students' alcohol and marijuana use from the 1993, 1997 and 1999 waves of the CAS, which is a nationally representative study of full-time students at four year colleges. In 1993, a random sample of 173 schools were selected from the American Council on Education's list of accredited universities using probability weights proportional to the size of each college. The sample was then augmented to improve representation of women's colleges and small colleges. Out of a final sample of 195

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colleges, 140 (72%) chose to participate in the 1993 survey. Administrators at each college were asked to provide a random sample of undergraduates drawn from the total enrollment of full-time students, and strict guidelines were provided regarding how to generate this sample. Over 200 students from each school were sent an anonymous survey in February of 1993. The surveys were mailed to the students at their registered school addresses. Over 17 000 students (17 582) responded to the survey, although response rates did vary significantly across schools [4]. In addition to interviewing students, school administrators were interviewed to obtain detailed information pertaining to campus policies.

In 1997 and 1999, the original 140 colleges were resurveyed. One hundred thirty colleges participated in the 1997 survey, and 128 participated in the 1999 survey. The main reason given by colleges for not participating in the subsequent surveys was that they were unable to provide a random sample of students and their addresses within the time frame designated by the study. In 1997 and 1999, student samples were obtained using the same procedures as the 1993 survey, resulting in a sample of 15 685 students in 1997 and 14 907 students in 1999. School administrators were also re-interviewed to obtain information on changing alcohol and tobacco campus policies.

Of particular interest to this study is the student's self-reported use of alcohol and marijuana in the past month and the past year. In each survey, students were asked the following, 'How often, if ever, have you use marijuana (or hashish)?' A dichotomous indicator was created indicating past year use if an individual responded that they had either consumed marijuana 'More than 30 days ago, but less than a year ago', 'More than a week ago, but less than 30 days ago', or 'Within the last week.' An indicator for use in the past month was constructed on the basis whether the respondent reported having last consumed marijuana 'More than a week ago, but less than 30 days ago', or 'Within the last week.'

Information on the student's past use of alcohol comes from the following question, 'When did you last have a drink (that is more than just a few sips)?' Separate dichotomous indicators set equal to one were constructed for those students who reported using alcohol within the past 12 months, and within the past 30 days. Information on the quantity of alcohol consumed is also collected in the CAS. However, similar information is not collected for marijuana use. Therefore, in order to give an equal treatment to marijuana and alcohol in our investigation into the economic relationship between these two drugs, we confine our analysis to the participation decision.

In addition to information on smoking marijuana and drinking, the student survey obtained detailed socioeconomic and demographic information. Thus it is possible to construct controls for important correlates of young adult substance use identified in the literature. Variables constructed for this analysis include: the age of the respondent (in years), age squared, an indicator for gender (male), race (White, Black, Asian, Native American), ethnicity (Hispanic, non-Hispanic), the religion that they grew up in (Catholic, Jewish, Moslem, Protestant, other religion, and no religion), and indicators of each parent's drinking behavior while the respondent was growing up (parent not present, abstainer, former drinker, infrequent or moderate drinker, heavy or problem drinker). Although personal income is included in the questionnaire in 1997 and 1999, it was excluded in the original questionnaire in 1993. As we did not want to lose an entire wave of the survey, our analysis controls for income using a measure of parents' education (at least one parent completed college), which is available in all three waves. Sensitivity analyses showed that our main findings are not sensitive to the omission of the personal income variable that was collected in the last two waves of the survey. The college level characteristics controlled for are: an indicator for the college being a women's college, a historically black college, a commuter college, a small private college, a large private college, a large public campus, a small public campus.

Price and policy variables

Information on the full price of marijuana and alcohol has been merged into the CAS data from a variety of sources. Information on the monetary price of marijuana come from various publications of the Illegal Drug Price/Purity Report, (IDPPR) published by the DEA Office of Intelligence or Intelligence Division of the US Department of Justice. Although other sources of marijuana price data are available, the IDPPR published data represents the only source we are aware of in which it is possible to distinguish high and low quality marijuana consistently over time for the

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same locations. The IDPPR report the minimum and maximum retail (ounce) and wholesale (pound) price of commercial-grade and sinsemilla marijuana in 19 cities located in 16 states. These 19 cities represent main branch offices for the DEA. The price and quality information are obtained for purchases made by undercover police officers and DEA agents that are sent to a laboratory at the University of Mississippi for analysis. For the purposes of this analysis, we focus on the quarterly prices for commercial marijuana sold at the retail level, because we believe that this is the price that would be most relevant to young adults' consumption decisions. In addition, there is some evidence that commercial grade marijuana dominated the US market during this period [19]. Descriptive statistics for the DEA price of a ounce of commercial grade marijuana (in 1982–1984$) by year and site are presented in Tables A1 and A2 of the appendix.

There are two principal limitations of the DEA 19 cities data. First, quarterly data are not complete for all cities in each year and are particularly sparse in the later part of the 1990s. In order to produce a complete and consistent price series for our analysis, we make use of the full set of information we have on the minimum retail price for commercial marijuana, which includes quarterly observations from 1982–1998, by forming the predicted price based on the following regression model:

$$\ln\left(\frac{p_{jt}}{\mathrm{CPI}_t}\right) = \sum_j \beta_{1j}\mathrm{city}_j + \beta_{2j}\mathrm{city}_j{*}\mathrm{year}_t + \mathrm{year}_t^2 + \varepsilon_{jt}$$

Here p_{jt} is the minimum retail price of commercial marijuana in city j in time period t, city_j ($j = 1, \ldots, 19$) is a set of city dummies for the DEA 19 cities, and year is a time trend. Since our measure of marijuana use is use in the past year and it is obtained in the first quarter of each calendar year, we match the predicted price in year t-1 to our survey data in year t.

A second limitation of these data is that they exist only for 19 locations in 16 states. However, several DEA branch offices report to each of these 19 cities offices. We used this additional information to assist us with matching college campuses to city-specific prices by matching each college to the closest within-state branch office that reported data to a 19 cities office. Each college campus was assigned a price for marijuana corresponding to the 19 cities office that their matched DEA branch office reported to. Although specific campuses are matched to different branch offices, these branch offices report only to the 19 cities offices, so several schools are inevitably given the same predicted price. This price may be a better or worse approximation for the actual price faced by students at a particular school depending on the fraction of purchase observations that came from the campus' matched DEA branch office as well as the local variation in price in that area.

Because we are concerned about the measurement error that is introduced by matching 140 schools in 40 states to price data available only in 19 specific cities, we include an additional proxy to help us capture the variation in the expected price across colleges. This measure is the distance between the school location and the matched DEA branch office location. The intuition behind the inclusion of this variable is based on the assumption that DEA branch offices are concentrated on major drug traffic routes and that the price of marijuana is higher at locations farther away from these routes due to the higher transportation cost associated with delivering the drug to that location. If these assumptions are correct, then those schools closer to major drug routes are likely to experience lower prices than schools that are farther away. On this basis, we use the distance between the school location and the matched DEA branch office location as a measure of the component of the money price of marijuana associated with sellers transporting the drug to the school location. For those schools in which a out of state branch was geographically closer than the within-state DEA branch match, we created an additional indicator specifying that an out-of-state match was closer to correct for any measurement error introduced by these poor quality matches.

In addition to the money cost, the full price of marijuana use includes the expected social and legal penalties faced. We attempt to account for state-level variation in these non-monetary components of price by including the state-level maximum fine for possession of one ounce of marijuana. We also experimented with the median fines within the state, but our results are qualitatively similar. Data on the legal penalties associated with possession of an ounce of marijuana were compiled from various secondary sources, including the Sourcebook of Criminal Justice Statistics and the National Organization for Reform of Marijuana Laws (NORML), for the years

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Table 1. Summary statistics[a]

Variable	Mean	Std. Dev.	Min	Max
Used marijuana in the past month	0.15	0.36	0	1
Used alcohol in the past month	0.69	0.46	0	1
Used marijuana in the past year	0.27	0.44	0	1
Used alcohol in the past year	0.82	0.38	0	1
Price of an oz of commercial grade marijuana	62.95	18.83	26.70	108.12
Miles from DEA site to college	33.32	36.28	0.30	168
Out of state match between college & DEA office	0.04	0.19	0	1
Maximum fine for possession of an oz. of marijuana ($'000's)	3.56	26.12	0	299.40
Indicator for marijuana use is decriminalized	0.29	0.45	0	1
Indicator for alcohol consumption banned on campus	0.19	0.39	0	1
Indicator for alcohol free dorms are available on campus	0.49	0.50	0	1
Indicator for one off-campus bar within mile of campus	0.03	0.16	0	1
Indicator for more than one off-campus bar within mile of campus	0.89	0.31	0	1
Federal plus state beer tax	1.92	0.42	1.45	4.25
Indicator for State restricts happy hour sales	0.46	0.50	0	1
Indicator for State restricts pitcher sales	0.42	0.49	0	1
Indicator for State restricts open containers	0.52	0.50	0	1
Price of cigarettes	2.32	0.51	1.53	3.60
Male	0.41	0.49	0	1
Age	21.01	2.24	15	26
Age squared	446.46	97.67	225	676
Hispanic	0.06	0.24	0	1
African American	0.05	0.22	0	1
Asian	0.07	0.26	0	1
Native American	0.01	0.08	0	1
Other Race	0.06	0.25	0	1
Raised Catholic	0.37	0.48	0	1
Raised Jewish	0.03	0.18	0	1
Raised Moslem	0.01	0.09	0	1
Raised Protestant	0.37	0.48	0	1
Raised other religion	0.10	0.30	0	1
One parent completed college	0.81	0.39	0	1
No father present	0.03	0.16	0	1
Father former drinker	0.02	0.15	0	1
Father infrequent or moderate drinker	0.63	0.48	0	1
Father heavy or problem drinker	0.11	0.32	0	1
No mother present	0.01	0.09	0	1
Mother former drinker	0.01	0.08	0	1
Mother infrequent or moderate drinker	0.60	0.49	0	1
Mother heavy or problem drinker	0.03	0.16	0	1
Womens' college	0.04	0.20	0	1
African American College	0.01	0.11	0	1
Commuter college	0.14	0.35	0	1
Small private college	0.12	0.32	0	1
Large private college	0.16	0.37	0	1
Small public college	0.14	0.35	0	1
Year = 1993	0.34	0.47	0	1
Year = 1997	0.37	0.48	0	1

[a] All monetary variables are measured in $1999.

1990–1997. Penalty information for 1999 come from original legal research conducted by The MayaTech Corporation as part of the ImpacTeen: State Illicit Drug Project.

Much of the previous literature has employed an indicator for whether marijuana use has been decriminalized in the respondent's state of residence as a measure of the legal risk of using

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Table 2. Alcohol and marijuana use

	Marijuana use		
Alcohol use	No	Yes	Total
Past month			
No	0.308	0.007	0.315
Yes	0.544	0.141	0.685
Total	0.852	0.148	1.000
Past year			
No	0.174	0.003	0.177
Yes	0.560	0.263	0.823
Total	0.734	0.266	1.000

marijuana. States that have decriminalized marijuana are presumed to have lower criminal penalties associated with possession of specified amounts. However, new research by Pacula *et al.* [20] shows that this variable does not capture real differences in the criminal penalties for marijuana use across states in the United States. Nonetheless, their research finds that decriminalization remains significant in demand equations that include a full set of measures representing the legal risk of using marijuana. This suggests that decriminalization still captures something unobservable about the state, possibly greater public knowledge of reduced penalties associated with marijuana possession or other positive societal norms. So that our results can be compared to other studies evaluating demand, we include and indicator for state decriminalization status in some of our specifications.

Information on the monetary cost of alcohol is proxied by the CPI deflated sum of federal and state taxes on a 12-ounce can of beer. These data are published annually in the Beer Institute's Brewers' Almanac. Although beer is not the only alcohol beverage consumed by college students, it is frequently reported as the drink of choice [8] and thus is perhaps the most relevant for this analysis. Tax information is used instead of price information because of its policy relevance. Various studies have shown that the effect of price on the demand for alcohol is qualitatively similar regardless of whether price is defined in terms of the beer tax or the real price of beer [11,21]. Furthermore, there is some evidence that 100% of the tax on beer is passed on to the consumer [22].

We measure non-monetary aspects of the full price of alcohol by state and campus level variables related to access and opportunity to use. In terms of state level policies governing access, we include indicators for state level restrictions on happy hours, state level restrictions on low price sales, and state level open container laws. We capture campus level access to alcohol using an indicator for the school banning alcohol use on campus for all students and an indicator for the school offering substance free dorms. To capture off-campus access to alcohol, we include a set of indicators representing whether there is 0, 1 or more than 1 bar within a mile radius of the school campus. A continuous measure of the number of bars within a one mile radius was not available for all three years.

Several studies have found interdependencies in the demands for alcohol, marijuana and cigarettes. In order to control for this in our examination of the relationship between alcohol and marijuana, we also include the price of cigarettes in our models. We merge data on the state average price of cigarettes, obtained from various publications of the Tobacco Institute's Tax Burden on Tobacco, based on the state location of the school campus. The cigarette price is a state average cigarette price, based on the price of single cigarette packs, cartons and vending machine sales. It reflects the average price of a branded pack of 20 cigarettes inclusive of state level excise taxes. Demand equations for cigarettes are not explicitly examined here because school cigarette policy variables, which have been shown to be correlated with cigarette use among college populations, are only available for the 1997 and 1999 surveys.

Descriptive statistics for the pooled sample of the 1993, 1997 and 1999 waves of the CAS, along with price and policy variables are reported in Table 1. The sample size of 37 673 reflects the number of observations for which we have non-missing data.

Table 2 contains simple cross tabulations of marijuana and alcohol use in the past month and year. Amongst college students surveyed, approximately two thirds (four fifths) had used alcohol in the past month (year), and about 15% (27%) had used marijuana during the same time period. It is also noteworthy that while the majority of students who use alcohol do not use marijuana, practically all marijuana users also consumed alcohol during the same time period.

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As discussed in the previous section, omitted state level characteristics may potentially bias our estimates of the effect of our price and policy variables if the omitted factors are correlated with these variables. In order to address this issue, we include a set of state indicators in our models of marijuana and alcohol use. However, because there has been almost no change in several of our key state-level policies variables, particularly the state decriminalization status, beer tax, and legislation governing happy hours, low price alcohol sales, and open containers during the time period under analysis, there is insufficient information to identify the effects of these policy variables in addition to the set of state indicators. Rather than omit these policy variables from our analysis completely, our strategy is to estimate models without state effects that include these policy variables in addition to models with state effects. While allowing us to ascertain the role of these important policy variables in the decision to participate in alcohol and marijuana use, this approach also facilitates an investigation into the nature of potential biases introduced by omitting state indicators.

Results

In this section, we present the results from estimating 30 day and annual participation equations for marijuana and alcohol use. The focus of our analysis is in establishing the economic relationship between alcohol and marijuana for college students. Because of this we only present findings on measures of the full price of alcohol and marijuana in the text. Tables A3 and A4 in the Appendix contain the full set of results for 30-day prevalence of alcohol and marijuana use, respectively.

Price and policy variables

Tables 3 and 4 contain the estimated marginal effects and asymptotic z-scores for the bivariate probit model of participation in marijuana and alcohol use in the past 30 days and the past year, respectively. The top panels of both these tables present findings from specifications that include state identifiers. The lower panels present findings from specifications that exclude state identifiers but include marijuana decriminalization status, the beer tax, and state restrictions on happy hours, pitcher sales, and open containers. Standard errors in all of these models are adjusted for the clustering of observations at the school level. Although theory would suggest that clustering at the 19 cities level would be more appropriate for interpreting the coefficient on price, standard errors obtained from clustering at the school level are more conservative and are thus presented for all variables.

Following Peters [23], a generalized RESET test is employed to assess the overall adequacy of the estimated models. Because the literature does not provide guidance as to the order of the polynomial in the linear predictor that should be included in the auxiliary equation for the RESET test, we report results for two versions of the test. The first is based on the generated regressor, $\hat{p}_i^2$, in an auxiliary estimation where $\hat{p}_i = \hat{\beta}' x_i$ is the estimated linear predictor from the original model. The second version of the test includes both squared and cubic terms of the linear predictor in an auxiliary equation. The hypothesis being tested is that the coefficient(s) on the polynomial term(s) in the linear prediction are (jointly) zero. The p-values for these test are contained in Tables 3 and 4.

As the main results are robust to our measure of past use, the following discussion focuses on the findings from the past month prevalence equations presented in Table 3. Looking first at the models with state indicators included and using a 5% level of significance, we find that the equation for marijuana use and the equation for alcohol use pass the RESET test when only a quadratic term is included in the auxiliary regression. When the RESET test is based on both a quadratic and cubic term in the auxiliary equation, the estimated model for marijuana use just passes and the estimated model for alcohol use just fails the test. This suggests that model misspecification may be an issue for the alcohol use equation, and that caution should be used when interpreting the results for this equation. This issue will be revisited when differences by gender are examined.

Turning to the results for past month marijuana use, we find that both measures of the money price of marijuana (the DEA 19 cities matched price and the number of miles between the respondent's school and the closest DEA reporting office) are significantly negatively related to marijuana use in the past month (one-sided test). This provides

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Table 3. Thirty day prevalence of marijuana and alcohol use

	Marijuana		Alcohol	
	$dP(M=1)/dx$	z-score	$dP(M=1)/dx$	z-score
State indicators included ($N = 37673$)				
Price of an oz of commercial grade marijuana	−0.0006	−1.69	−0.0009	−2.03
Miles from DEA site to college	−0.0003	−2.55	0.0000	−0.16
Out of state match	0.0237	0.60	−0.0349	−0.64
Max fine for possession of marijuana	0.0002	1.53	−0.0001	−0.69
Alcohol consumption banned on campus	−0.0183	−2.11	−0.0382	−2.04
Alcohol free dorms are available on campus	0.0056	1.03	0.0021	0.24
One off campus bar within a mile of campus	0.0028	0.16	0.0312	0.79
Greater than one off campus bar within a mile of campus	−0.0074	−0.43	0.0370	1.77
Cigarette price	−0.0213	−1.06	−0.0225	−0.77
Rho (p-value for Ho: Rho = 0)	0.57		(0.00)	
p-value for Ho: coefficient on $\hat{p}_i^2 = 0$	0.11		0.82	
p-value for Ho: coefficients on $\hat{p}_i^2$ & $\hat{p}_i^3 = 0$	0.06		0.04	
No state indicators included ($N = 37673$)				
Price of an oz of commercial grade marijuana	0.0001	0.22	−0.0003	−0.86
Miles from DEA site to college	−0.0005	−3.40	−0.0001	−0.42
Out of state match	0.0376	1.37	−0.0297	−0.67
Max fine for possession of marijuana	0.0003	2.63	−0.0001	−0.29
Decriminalization	0.0132	1.20	0.0060	0.28
Alcohol consumption banned on campus	−0.0408	−4.03	−0.0927	−3.20
Alcohol free dorms are available on campus	0.0044	0.74	−0.0001	−0.01
One off campus bar within a mile of campus	0.0178	0.80	0.0758	1.30
Greater than one off campus bar within a mile of campus	−0.0023	−0.12	0.0962	2.31
Beer tax	−0.0152	−1.07	−0.0388	−1.59
State level restrictions on happy hours	−0.0175	−1.78	−0.0261	−1.72
State level restrictions on low prices	0.0033	0.30	0.0204	1.04
State level open container laws	−0.0138	−1.52	−0.0330	−2.01
Cigarette price	0.0095	0.56	−0.0160	−0.59
Rho (p-value for Ho: Rho = 0)	0.57		(0.00)	
p-value for Ho: coefficient on $\hat{p}_i^2 = 0$	0.14		0.51	
p-value for Ho: coefficients on $\hat{p}_i^2$ & $\hat{p}_i^3 = 0$	0.00		0.00	

evidence that, as with other illicit and licit drugs, marijuana use is price responsive. The own price elasticity for participation in monthly (annual) marijuana use is estimated to be –0.24 (−0.20). In addition, the DEA 19 cities matched price is negative and significant in the alcohol use equation, suggesting a complementary relationship between alcohol and marijuana.

The non-monetary costs of using an illicit drug such as marijuana include the expected legal and social sanctions. We attempt to account for these costs with the maximum fine for marijuana possession. *Ceteris paribus*, we expect that greater legal sanctions increase the cost of using marijuana, and hence reduce the probability of use. However, this variable is estimated to have a statistically insignificant small positive impact on the prevalence of marijuana use. When we compare the findings for this variable in models with and without state identifiers, it is clear by the fact that the coefficient on maximum fine declines both in magnitude and significance that the state identifiers are picking up some of the omitted variable bias caused by unmeasured enforcement patterns.

Turning to the impact of the campus level alcohol policy variables in the model with state effects, we find that banning the consumption of alcohol on campus reduces participation in both alcohol and marijuana use. Our second measure of access to alcohol at the campus level, the set of indicators for the number of outlets selling alcohol

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within a mile of campus, has a positive and significant impact on the probability of alcohol use in the past 30 days, but has no statistically significant impact on marijuana use. Neither the provision of alcohol free dorms, nor the price of cigarettes is found to significantly affect either the decision to use alcohol or marijuana in the past 30 days.

State indicator variables are included in the models of substance use in an attempt to account for omitted or unobserved state level characteristics associated with use that are potentially correlated with included policy variables. However, addressing this issue comes at the cost of investigating the impact of the effect of state level policy variables, such as the legal status of marijuana use, the state and federal taxes on beer, and state level restrictions on happy hours, low prices, and open container laws, which exhibit very little variation over time. The high degree of multicollinearity between these particular policy variables and state indicators means that the effects of the variables cannot be separately identified from the state indicators. In order to investigate the role of these important policy variables, we now turn to the results for models estimated without state effects.

To the extent that decriminalization of the use of marijuana represents greater knowledge of reduced penalties within a state (through an

Table 4. Annual prevalence of marijuana and alcohol use

	Marijuana		Alcohol	
	$dP(M=1)/dx$	z-score	$dP(A=1)/dx$	z-score
State indicators included ($N = 37673$)				
Price of an oz of commercial grade marijuana	−0.0008	−1.87	−0.0006	−1.79
Miles from school to 19 cities match	−0.0005	−3.09	−0.0002	−1.15
Out of state match	0.0248	0.44	−0.0092	−0.31
Max fine for possession of marijuana	0.0003	1.40	0.0001	0.54
Alcohol consumption banned on campus	−0.0240	−1.78	−0.0232	−1.73
Alcohol free dorms are available on campus	0.0106	1.34	−0.0027	−0.45
One off campus bar within a mile of campus	0.0003	0.01	0.0041	0.16
Greater than one off campus bar within a mile of campus	−0.0018	−0.07	0.0161	1.09
Cigarette price	−0.0231	−0.89	−0.0243	−1.11
Rho (p-value for Ho: Rho = 0)	0.65		(0.00)	
p-value for Ho: coefficient on $\hat{p}_i^2 = 0$	0.18		0.73	
p-value for Ho: coefficients on $\hat{p}_i^2$ & $\hat{p}_i^3 = 0$	0.01		0.00	
No state indicators included ($N = 37673$)				
Price of an oz of commercial grade marijuana	0.0000	−0.003	−0.0003	−0.96
Mile from school to 19 cities match	−0.0008	−3.81	−0.0002	−1.03
Out of state match	0.0497	1.38	−0.0079	−0.26
Max fine for possession of marijuana	0.0004	2.63	0.0000	0.15
Decriminalization	0.0151	0.96	0.0172	0.97
Alcohol consumption banned on campus	−0.0604	−3.82	−0.0703	−2.87
Alcohol free dorms are available on campus	0.0099	1.15	−0.0042	−0.53
One off campus bar within a mile of campus	0.0289	0.74	0.0499	1.24
greater than one off campus bar within a mile of campus	0.0023	0.08	0.0691	1.99
Beer tax	−0.0269	−1.28	−0.0328	−1.75
State level restrictions on happy hours	−0.0248	−1.82	−0.0222	−2.08
State level restrictions on low prices	0.0104	0.66	0.0261	1.81
State level open container laws	−0.0157	−1.18	−0.0308	−2.40
Cigarette price	0.0285	1.18	−0.0285	−1.40
Rho (p-value for Ho: Rho = 0)	0.66		(0.00)	
p-value for Ho: coefficient on $\hat{p}_i^2 = 0$	0.18		0.03	
p-value for Ho: coefficients on $\hat{p}_i^2$ & $\hat{p}_i^3 = 0$	0.12		0.01	

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Table 5. Thirty day prevalence of marijuana and alcohol use

State indicators included ($N = 37673$)	Marijuana		Alcohol	
	$dP(M=1)/dx$	z-score	$dP(M=1)/dx$	z-score
Price of an oz of commercial grade marijuana	−0.0007	−1.90	−0.0009	−1.95
Miles from school to 19 cities match	−0.0003	−2.22	0.0000	−0.12
Out of state match	0.0230	0.63	−0.0544	−0.88
Max fine for possession of marijuana	0.0003	1.74	0.0001	0.59
Alcohol consumption banned on campus	−0.0253	−2.34	−0.0536	−2.66
Alcohol free dorms are available on campus	0.0037	0.58	0.0005	0.05
One off campus bar within a mile of campus	0.0193	0.88	0.0287	0.70
Greater than one off campus bar within a mile of campus	0.0006	0.04	0.0386	1.61
Cigarette price	−0.0209	−1.03	−0.0126	−0.41
Male* Price of an oz of commercial grade marijuana	0.0002	0.87	−0.0002	−0.57
Male* miles from school to 19 cities match	−0.0001	−0.58	0.0000	−0.02
Male* out of state match	−0.0005	−0.03	0.0433	1.47
Male* max fine for possession of marijuana	−0.0002	−1.92	−0.0002	−1.02
Male* alcohol consumption banned on campus	0.0183	1.43	0.0360	2.54
Male* alcohol free dorms are available on campus	0.0048	0.51	0.0036	0.31
Male* one off campus bar within a mile of campus	−0.0385	−1.64	0.0117	0.31
Male* greater than one off campus bar within a mile of campus	−0.0208	−1.22	−0.0050	−0.23
Male* cigarette price	−0.0009	−0.07	−0.0321	−1.38
Rho	0.57			
p-value for Ho: Rho = 0	0.00			
Log-likelihood	−34109.50			
p-value for Ho: coefficient on $\hat{p}_i^2 = 0$	0.33		0.36	
p-value for Ho: coefficients on $\hat{p}_i^2$ & $\hat{p}_i^3 = 0$	0.18		0.08	

advertising effect) or some other state unobservable (e.g. less enforcement of marijuana law pertaining to lower quantities), it is expected to positively impact the probability that a person uses marijuana. While the results in Table 3 and 4 support the hypothesized positive association between marijuana use and its decriminalized status in this sample of college students, this association is imprecisely estimated. Living in state that has decriminalized marijuana use is also associated with a higher prevalence of alcohol use, consistent with economic complementarity, although, once again the effect is not precisely estimated. This imprecision, resulting in a lack of statistical significance of the effect of decriminalization in all models is not surprising in light of the fact that we do not really know what decriminalization status is representing for this population.

We find that the beer tax, our proxy for the money price of alcohol, has a negative impact on the prevalence of both alcohol and marijuana use. Its effect is, however, imprecisely estimated and only reaches statistical significance (at the 5% level using a one-sided test) for alcohol use in the past year, providing weak evidence that alcohol consumption is price responsive. We further interpret the (statistically insignificant) negative effect of the beer tax in the marijuana prevalence equation as supporting our general finding of a complementary relationship between these two substances. Similarly, state level policy variables that impact access to alcohol also tend to support the economic relationship between alcohol and marijuana as complementary. In particular, we find that happy hour restrictions have a significantly negative impact on both marijuana and alcohol use (using a one-sided test). Open container laws, which significantly reduce the prevalence of drinking also have a negative effect on marijuana use, although this finding is not significant at conventional levels.

Although the exclusion of state level indicators generally increases the significance of policy variables previously found to be important, there

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is one very notable exception: the 19 cities matched price of marijuana. When state identifiers are omitted from the model, the estimated marginal effect of the 19 cities DEA marijuana price is substantially reduced and it becomes statistically insignificant. Given that our DEA price data cover 19 cities in 16 states, this suggests to us that the state identifiers are capturing important unobserved state-level variation in price. We do not interpret the lack of a significant effect of the DEA matched price (in models without state effects) as evidence that marijuana use is unresponsive to changes in its own price because we still find a negative and statistically significant finding for our second measure of the monetary price of marijuana: the miles between college and DEA reporting office. This variable is interpreted as measuring the higher transportation costs faced by dealers who sell marijuana at colleges farther away from major drug routes.

Differences across gender and age

Previous findings of a differential response of substance use to policy variables by gender and age-group suggest that an investigation of the robustness of our findings across these subpopulations is warranted [14,13]. The usual approach to examining whether sub-samples can be pooled is the standard likelihood ratio (LR) test, which compares the unrestricted model (which allows for differential responses across subgroups) to the restricted model (imposing no differences across groups). However, when data are clustered, as ours are, the observations are no longer independent, and so the joint distribution function for the sample is not the product of the distribution functions for each observation. Since the likelihood used to estimate coefficients does not reflect the correlation among observations, testing should be carried out using the Wald test, rather than the LR test. This test is based on the unrestricted model, which allows for differential responses by group.

In testing for gender (age) differences, we estimate the unrestricted bivariate probit model for marijuana and alcohol use in the past thirty days (with state fixed effects) by including a full set of interaction terms between regressors and an indicator for gender is male (student of legal drinking age). Similar models were estimated looking at annual prevalence with and without state fixed effects, and the findings presented here are robust across all these specifications.

Before examining the evidence regarding differential response by gender, we examine the overall adequacy of the model with the RESET test. As can be seen from Table 5, this model passes both versions of the REST test. This suggests that the failure of the alcohol use equation reported in Table 3 to consistently pass the RESET test may be due to the imposition of a common response to policy and other control variables by gender. The validity of this restriction is now examined.

The Wald test for whether there is any significant difference in response between males and females (minors and students 21 years or older) is a test of joint significance of these interaction terms with the indicator for gender is male (age is at least 21). The p-values associated with the test of the joint significance of the interaction terms in both equations is <0.0001 (<0.0001). We conclude that there are significant differences across gender (age) in the response to at least one of the regressors.

One of the benefits of using the Wald testing procedure is that, in addition to testing the joint significance of all interaction terms, it facilitates examining whether subsets of coefficients differ significantly across sub-groups. Of particular interest to this study is whether responses to policy variables are significantly different. Beginning with the results for males and females, the p-value for the test of the joint significance of the interaction terms on the policy variables in the marijuana and alcohol use equations is 0.001, indicating that there is a differential response to at least one of these variables across gender. Table 5 presents the estimated marginal effects of the price and policy variables (for the base category, gender is female), the marginal effects for the interaction terms (with an indicator for gender is male), and the corresponding asymptotic z-scores for the bivariate model of marijuana and alcohol use in the past 30 days. Inspection of the significance of the interaction terms reveal that the only policy variable that has a statistically significant differential affect on males in the alcohol participation equation is the ban on drinking on campus variable. As can be seen in Table 5, bans have a significantly negative impact on the use of alcohol and marijuana for the base category, females. However, the effect of bans on alcohol use by males (the sum of the effect for the base category and the interaction term) is not significantly different from zero. There is some

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weak evidence that males' and females' participation in marijuana use have a differential response to fines for the possession of marijuana and attending a campus with one bar within a mile of the campus, although the effect of these variables is imprecisely estimated for both males and females.

The results from this analysis find no evidence of a significant difference in the effect of the price of marijuana on either alcohol or marijuana use across gender. The findings with respect to the monetary price of marijuana suggest that alcohol and marijuana are economic complements for both males and females. The conclusion of complementary is further supported by the negative and statistically significant affect of bans on both alcohol and marijuana consumption for females, and by the negative and statistically significant affect of bans on marijuana consumption for males.

We follow the same strategy to determine whether there are age differences between college students in terms of their response to policy variables. The *p*-value for testing the null hypothesis that the interaction terms on the policy variables are jointly insignificant in the bivariate probit model for alcohol and marijuana use is 0.35. We therefore conclude that there is insufficient evidence to indicate a difference in the response to any of the policy variables on alcohol and marijuana use across these two age groups. Demographic and background variables, such as gender and parental drinking, appear to be driving the differences in demand of students who are minors compared to those of legal drinking age.

Discussion

It is extremely difficult to draw a clear conclusion of the relationship between the demands for alcohol and marijuana from the existing literature for several reasons. First, many of the early studies suffer from a clear omitted variable bias due to the exclusion of a measure for the price of marijuana. Second, studies have been conducted on cohorts drawn from different time periods (1980s versus 1990s) and at different points in the life-cycle (high school seniors, young adults, all adults). It is entirely possible that the relationship between the demands for these two substances varies by age and is influenced by larger social trends that are unique to specific cohorts. Finally, current measures of alcohol use employed by social scientists (e.g. use in the past year or use in the past month) represent very different drinking behaviors and drinking populations, and thus findings with respect to a particular measure of drinking behavior may not be generalizable to other drinking behaviors.

In this study we attempt to overcome many of these limitations by focusing on a single population, college students, from a single period (the 1990s). We further attempt to address the problem of aggregation and/or sampling bias by doing additional analyses by gender and age (minor vs adult). We include the best measure of marijuana prices available to us so as to reduce the influence of omitted variable bias. We recognize, however, that our price variable is imperfectly measured and hence try to reduce the effect of measurement error by including measures of the 'quality' of our price data in all our analyses. Finally, we examine the relationship between marijuana use and two specific drinking behaviors that are more easily compared to other populations: use of alcohol in the past year and use of alcohol in the past month.

Given these parameters, the evidence from this study, generated from examination of own- and cross-price effects, suggests that alcohol and marijuana are economic complements for college students. The strongest and most consistent evidence comes from findings with respect to the price of marijuana, which is shown to be negatively related to both alcohol and marijuana participation. This negative relationship between price and participation does not appear to be driven by any one particular demographic group dominating the sample, although insufficient sample size precludes us from doing a careful analysis by race/ethnicity.

In addition to finding a negative relationship between the monetary price of marijuana and the probability of using both marijuana and alcohol, results with respect to college level measures of social access to alcohol also support a complementary relationship. In particular, campus bans on alcohol use are associated with a lower probability of using alcohol and marijuana in the general model, for females, and across different age groups. The statistical significance of this relationship remains for males' marijuana use, although it appears that males' alcohol use is not responsive to college level bans. It may be the case that men are less sensitive to college drinking bans because of self-selection, i.e. men who think it is important to

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drink on campus go to schools that allow drinking on campus. A more careful analysis that enables researchers to account for self-selection into colleges may provide additional insight regarding the significance of this differential finding. Evidence from models including the beer tax and state level policies governing access to alcohol provide further support for a complementary relationship between alcohol and marijuana use for the full sample and all sub-samples evaluated.

The evidence from this study suggests that recent efforts to reduce college students' social access to alcohol has not contributed to the rise in marijuana use among this group. In particular, we find that campus bans on alcohol use are associated with a lower prevalence of marijuana use. In addition, state-level efforts to reduce college drinking, such as prohibiting happy hours, also appear to reduce the prevalence of both alcohol and marijuana use during this time period. Our results suggest that the more likely explanation for the rise in marijuana use among college students is the fact that college students' use of marijuana is price responsive. Given that the price of marijuana has dropped significantly during the past decade, it is not surprising that the prevalence of use in this price responsive group has risen [24].

If alcohol and marijuana are truly economic complements for college students, as our study suggests, then several important policy implications can be drawn. First, it implies that the high marijuana prices associated with its prohibition have the added benefit of diminishing alcohol use in this high-risk population. A second policy implication of this study is that policies that are effective at reducing drinking among college students, such as banning the consumption of alcohol on campus and prohibiting happy hours, appears to have the additional benefit of reducing marijuana use as well.

One final observation warrants mentioning. In all of the models evaluated, we included a measure of the price of cigarettes to help control for interdependencies in the demands for alcohol, marijuana and cigarettes. However, in our sample the price of cigarettes has an insignificant effect on both alcohol and marijuana use in all specifications. This suggests that for college students there is no significant relationship between cigarettes and alcohol use and/or cigarettes and marijuana use, but further investigation may be warranted given that we do not control for other aspects of tobacco control policy.

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Appendix A

The price of an ounce of marijuana by year and site are given in Table A1 and Table A2. The full set of bivariate probit results for 30-day prevalence of alcohol and marijuana use are given in Tables A3 and A4 respectively.

Table A1. The DEA 19 cities price of an ounce of commercial quality marijuana: by year

Year	*N*	Mean	Standard deviation
1993	55	74.62	37.58
1994	54	67.86	34.35
1995	53	74.29	47.56
1996	56	67.14	35.98
1997	37	50.82	23.26
1998	41	55.24	30.64
1999	29	53.1	29.1

Table A2. The DEA 19 cities price of an ounce of commercial quality marijuana: by site

Site	*N*	Mean	Standard deviation
1	21	81.96	31.59
2	25	63.11	42.42
3	18	96.98	25.51
4	18	49.01	19.02
5	7	130.34	62.33
6	22	66.76	25.92
7	18	34.79	10.85
8	10	134.16	61.67
9	19	50.37	12.49
10	12	67.79	3.08
11	14	79.26	49.13
12	23	60.40	18.39
13	25	71.30	18.91
14	15	40.26	9.68
15	4	46.61	17.02
16	14	50.18	43.75
17	7	108.55	25.48
18	9	75.72	18.00
19	21	59.00	13.10

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Table A3. Thirty day prevalence of alcohol use

	Without state effects		With state effects	
	$dP(A=1)/dx$	z-score	$dP(A=1)/dx$	z-score
Price of MJ	−0.00035	−0.86	−0.00093	−2.03
Miles from DEA site	−0.00013	−0.42	−0.00005	−0.16
Out of state match	−0.02966	−0.67	−0.03491	−0.64
Maximum real fine	−0.00006	−0.29	−0.00007	−0.69
Decriminalized state	0.00599	0.28		
College ban on alcohol	−0.09275	−3.20	−0.03820	−2.04
Alcohol free dorms	−0.00010	−0.01	0.00209	0.24
One bar within mile of campus	0.07582	1.30	0.03119	0.79
>1 bar within mile of campus	0.09625	2.31	0.03699	1.77
Real beer tax	−0.03878	−1.59		
State restricts happy hour sales	−0.02609	−1.72		
State restricts pitcher sales	0.02044	1.04		
State restricts open containers	−0.03299	−2.01		
Real price of cigarettes	−0.01598	−0.59	−0.02253	−0.77
Male	0.04603	7.91	0.04642	7.92
Age	0.48204	21.16	0.48068	21.35
Age squared	−0.01087	−20.47	−0.01077	−20.52
Hispanic	−0.02338	−1.90	−0.01480	−1.24
African American	−0.20500	−12.44	−0.21211	−14.77
Asian	−0.21927	−11.31	−0.22603	−16.67
Native American	−0.00084	−0.03	0.00002	0.00
Other Race	−0.07336	−5.13	−0.07119	−5.36
Raised Catholic	0.03902	4.40	0.03175	3.86
Raised Jewish	0.03848	2.23	0.02471	1.53
Raised Moslem	−0.21462	−6.82	−0.22969	−7.29
Raised Protestant	−0.05647	−6.63	−0.05432	−6.59
Raised other religion	−0.05868	−3.41	−0.03986	−3.76
One parent completed college	0.05482	6.86	0.05872	7.93
No father present	0.08090	5.10	0.07290	4.74
Father former drinker	0.09268	5.38	0.08178	4.96
Father infrequent or moderate drinker	0.13214	11.39	0.11671	16.67
Father heavy or problem drinker	0.10803	8.36	0.09623	9.10
No mother present	−0.08195	−3.04	−0.08324	−3.06
Mother former drinker	0.07577	2.94	0.07032	2.60
Mother infrequent or moderate drinker	0.09518	13.30	0.08708	13.79
Mother heavy or problem drinker	0.05414	3.42	0.04921	3.15
Womens college	−0.08615	−3.02	−0.08982	−3.04
African American College	−0.01736	−0.40	−0.04028	−1.23
Commuter college	−0.09775	−5.28	−0.08952	−4.24
Small private college	−0.03849	−1.39	−0.07646	−3.01
Large private college	−0.04384	−1.04	−0.01249	−0.65
Small public college	−0.02071	−0.70	−0.05871	−2.88
Year = 1993	−0.02546	−0.93	−0.02707	−0.95
Year = 1997	0.01623	0.56	0.01089	0.35

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Table A4. Thirty day prevalence of marijuana use

	Without state effects		With state effects	
	$dP(M=1)/dx$	z-score	$dP(M=1)/dx$	z-score
Price of MJ	0.00005	0.22	−0.00056	−1.69
Miles from DEA site	−0.00048	−3.40	−0.00033	−2.55
Out of state match	0.03764	1.37	0.02367	0.60
Maximum real fine	0.00027	2.63	0.00017	1.53
Decriminalized state	0.01323	1.20		
College ban on alcohol	−0.04076	−4.03	−0.01825	−2.11
Alcohol free dorms	0.00443	0.74	0.00561	1.03
One bar within mile of campus	0.01783	0.80	0.00282	0.16
>1 bar within mile of campus	−0.00232	−0.12	−0.00744	−0.43
Real beer tax	−0.01521	−1.07		
State restricts happy hour sales	−0.01754	−1.78		
State restricts pitcher sales	0.00334	0.30		
State restricts open containers	−0.01383	−1.52		
Real price of cigarettes	0.00952	0.56	−0.02129	−1.06
Male	0.04377	10.94	0.04333	10.97
Age	0.03451	2.45	0.03101	2.24
Age squared	−0.00100	−3.02	−0.00089	−2.76
Hispanic	−0.02383	−2.49	−0.01802	−1.88
African American	−0.03992	−4.01	−0.04005	−4.08
Asian	−0.07544	−9.90	−0.07452	−11.05
Native American	0.11000	3.81	0.11254	4.01
Other Race	0.01519	1.50	0.01387	1.44
Raised Catholic	−0.02488	−3.83	−0.02505	−4.37
Raised Jewish	0.05677	4.99	0.04766	4.13
Raised Moslem	−0.05297	−2.16	−0.05469	−2.28
Raised Protestant	−0.05236	−8.39	−0.04868	−8.34
Raised other religion	−0.03990	−4.80	−0.03313	−4.38
One parent completed college	0.03798	8.05	0.03731	8.31
No father present	0.06487	4.78	0.05794	4.48
Father former drinker	0.09213	6.61	0.08351	6.41
Father infrequent or moderate drinker	0.03345	5.75	0.02799	5.78
Father heavy or problem drinker	0.06856	7.98	0.06239	8.07
No mother present	−0.01963	−0.89	−0.01945	−0.89
Mother former drinker	0.04325	2.02	0.03762	1.79
Mother infrequent or moderate drinker	0.03022	5.76	0.02674	5.35
Mother heavy or problem drinker	0.07709	5.66	0.07148	5.58
Womens college	−0.06139	−2.89	−0.06372	−2.78
African American College	0.02653	1.09	0.01055	0.26
Commuter college	−0.03764	−3.17	−0.04100	−3.17
Small private college	−0.01862	−1.48	−0.01794	−1.33
Large private college	−0.02141	−1.48	−0.02619	−2.32
Small public college	0.00423	0.27	−0.01300	−0.95
Year = 1993	0.00402	0.25	−0.01999	−1.08
Year = 1997	−0.02531	−1.40	−0.05414	−2.59

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