

Marijuana and Alcohol: The Effects of Marijuana Legalization on Alcohol Consumption in Colorado and Washington

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Abstract

As marijuana legalization begins to spread across the nation, policymakers and individuals are increasingly concerned with the consequences-- positive and negative, intentional and unintentional. Currently, four states and the District of Columbia have legalized recreational marijuana programs, and twenty states already have recreational marijuana measures on the ballot for November 2016. One pressing question is how legalization will affect alcohol use. Consumption of each substance is considered a risky behavior, and many wonder how the legalization of one will impact consumption of the other. In this paper, we seek to understand if residents of Colorado and Washington treat marijuana and alcohol as economic substitutes or complements-- if recreational marijuana legalization increases or decreases alcohol consumption. We use national health survey data and tax revenue data from these states, which began recreational marijuana programs in 2014. Our analysis shows that marijuana legalization is correlated with an increase in binge drinking, but a decrease in overall alcohol consumption. Overall, our results support the substitution hypothesis, but more time, and therefore data, is needed to fully understand the effects of the policy change.

Introduction

Marijuana legalization has been a widely debated topic in recent years, and emotions cover the spectrum from fear to ecstasy. In the last two years, four states and the District of Columbia have voted to legalize recreational cannabis use, while twenty more have already put the measure on the November 2016 ballot. This social and political change raises questions about the positive and negative consequences, and whether the impact of legalization is net positive or net negative. There are many potential benefits and detriments to a more liberal cannabis policy that must be thoroughly analyzed, including but not limited to changes in crime rates, addiction, personal and public health, and tax revenue. Some of these effects will no doubt be negligible, but others might be shockingly significant.

One argument against recreational marijuana legalization is that society is better off without another legal drug, like alcohol, that people can use and abuse. However, this argument assumes that legalizing marijuana would simply add another vice to society. In reality, the relationship between marijuana and alcohol is probably more complex than this. The two goods are either substitutes or complements, meaning participants either consume them together or instead of each other. This idea sparks three plausible hypotheses. The first is the null hypothesis: the two goods are economically unrelated. In this case, marijuana legalization would have no effect on alcohol consumption, and can be encouraged or challenged for other reasons. The second is that the public treats marijuana and alcohol as complements, and consumption of one increases consumption of the other. This situation is believable as the two can be used together for what may be a more desirable experience, and the psychological impact of one substance could likely lead to a rise in use of the other. In this case, marijuana legalization would lead to an increase in the use of both substances. This hypothesis has a few implications.

While it may be favorable from a tax revenue standpoint, we can assume it would be socially destructive. Excessive alcohol use is considered unhealthy and a societal ill, as it is linked to an increase in addiction, violence, health problems, and traffic fatalities (Richardson, Budd 2003). Marijuana is also linked to a decrease in mental health. (Patton, et al. 2002). Due to these consequences of substance use, we will be operating under the assumption that mind-altering substances are economic bads, even if consumers desire them. The third hypothesis is that the public treats alcohol and marijuana as substitutes, and alcohol consumption will decrease as marijuana consumption increases. This is also a very believable flow of events. Both substances are depressants, and many people who enjoy the effect of one would also enjoy the effect of the other, and replace one with the other in many situations, or decrease spending on one to use the money on the other. The implications of this hypothesis are more complicated because it depends on the ratio of substitutability and the level of social detriment that comes out of each. If one unit of alcohol is replaced with one unit of marijuana, and we consider the two socially equal, the effect is null, but if one unit of marijuana replaces two units of alcohol then legalization has a positive effect. If, for example, alcohol is twice as socially damaging than marijuana, then a 1:1 switch to marijuana would be socially positive. In this paper we will not attempt to determine which substance is better or worse for society, but it is essential to understand that this is crucial to determining whether or not the substitution hypothesis is desirable.

In this paper, we seek to help define the relationship between marijuana and alcohol using data sources and methods that have not previously been combined. Previous research on this subject is fairly limited because of the obvious difficulty collecting marijuana use data and the small sample of available data since 2014 recreational legalizations. Regardless, researchers have come up with creative ways to help answer this question, which will be covered more fully

in the Literature Review section. There is research supporting all three possibilities, but the majority of the research is evidence in favor of either the null hypothesis or the substitutes hypothesis. In this paper, we will explore the question in a different way, expanding the database of research on this subject and providing evidence for one of the hypotheses.

Literature Review

The relationship between alcohol and marijuana consumption is difficult to measure due to the legal issues surrounding the latter, but researchers have innovative ways to measure consumption of each and how they affect each other. Several studies use alcohol related crime data as a measurement, one of which tracks youth traffic fatalities, which are very often linked to alcohol, over periods of marijuana decriminalization (Chaloupka and Laixuthai, 1997). Their results show that traffic fatalities decrease when marijuana is decriminalized, suggesting that the substitution away from alcohol more than makes up for any possible driving while under the influence of marijuana. Another part of this study uses equations of utility as a function of intoxication level and various prices of alcohol, marijuana, and other drugs to find equilibrium. The prices included are market prices, difficulty of acquirement, and illegality. They find that youth growing up in states where marijuana is decriminalized drink less often and less heavily. Both parts of this study support the substitutes hypothesis.

Another study that finds evidence in support of this hypothesis is a study by D. Mark Anderson, Benjamin Hansen (the academic advisor of this study), and Daniel I. Rees (2013). They find that legalization of marijuana was associated with a decrease in alcohol related traffic fatalities, especially at night and on weekends when drinking is more common. This effect is moderated by the fact that alcohol is usually consumed outside of the home where transportation is necessary and marijuana consumption often takes place in the home, so it makes no

assumptions about the safety of driving while high. With legalization, the price of marijuana decreases, so as a normal good, the consumption of marijuana increases. Since we also observe that consumption of alcohol decreases, this is evidence that the two substances are substitutes. At the individual level, as medical marijuana laws came into effect fewer people reported drinking within the last month, and individuals on average reported fewer drinks consumed. This paper also uses data that shows beer and wine sales decreasing as medical marijuana becomes legal. In this study, the relationship between the two goods is measured in a myriad of ways using different techniques and data sources, all findings supporting the substitution hypothesis. This study sets a precedent for our hypothesis being the substitution hypothesis and our use of the BRFSS data, which we will touch on later.

Though many studies on this topic provide evidence for the substitution hypothesis, it is not a universal consensus, which motivated our research on this subject. One study by Yoruk and Yoruk (2011) analyzes the impacts of minimum drinking age laws on alcohol, tobacco, and marijuana consumption. The first time they did this study, they mistakenly did not include individuals in the sample who had not consumed alcohol or marijuana in they last 30 days. However, in 2012 Crost and Rees published their own paper in which they pointed out this flaw and remade the study using the full sample. They used a data set called the NLSY97, which reported the results of a twice conducted survey in which individuals ages 19-22 were asked about their smoking and drinking habits. Crost and Rees ultimate conclude the minimum drinking age laws have significant effects on alcohol consumption, but the effects on marijuana and tobacco consumption are negligible. This study favors the null hypothesis. Yoruk and Yoruk also published a fixed version of their original study in 2013, which also provides evidence for the null as drinking age laws effect on marijuana use was insignificant.

Other studies draw conclusions that may support the complementary hypothesis. In one study, Wen, Hockenberry and Cummings (2015) estimate the policy effect of medical marijuana laws in ten different states on the alcohol and marijuana behaviors of people. They find that for people over the age of 21, medical marijuana laws increased marijuana use and binge drinking, and they also increased the number of people 12-20 who tried marijuana at least once. However, one limit of this study is that the statistically significant link between drinking and marijuana use regards binge drinking, which people may treat differently than casual drinking. They ponder this possibility by hypothesizing that for people who like to drink to relax, marijuana and alcohol are substitutes, and for people who like to get the most intense feeling from drinking, they are complements. If this theory is true, it does not provide an answer for which effect would be stronger in the general population.

There is also a very recently published meta analysis on this very research question. Guttmannova et al. conducts a 2016 study that searches many research databases for peer-reviewed journals regarding the effects marijuana policy change have on alcohol consumption. 751 articles are reviewed in the study. Their conclusion is there is ample evidence for both substitution and complementary theories, and that there are more subtleties to the subject than simply every person treating the two goods the same. Worth mentioning is that one of their suggestions for future research is part of our study. They suggest analyzing the change in alcohol consumption in a state as that state's marijuana policies change. We accomplish this using data from Colorado and Washington.

Theory/Hypothesis

Based on the precedent set by the aforementioned studies, we expect to see evidence of the substitution effect taking place when marijuana is legalized. We hypothesize that demand (possession) legalization will reduce alcohol consumption and sales slightly, and supply (retail) legalization will further decrease alcohol consumption and sales. We expect that the substitution effect will be stronger for beer than for spirits or wine, based on the assumption that people who smoke recreational marijuana drink more beer, on average, than other types of alcohol.

Data

In this paper, we use three main datasets, which we modified to explore our hypothesis as accurately as possible. The first is the Behavioral Risk Factor Surveillance System (BRFSS), an annual survey published by the Center for Disease Prevention and Control that asks respondents an array of questions pertaining to risky behaviors and demographics. We aggregated the data sets from 2001 through January 2015 and generated relevant demographic variables and measures of alcohol consumption based on the available data. In doing this, we created repeated cross sectional survey that allows us to analyze the effects of different variables on different measures of alcohol consumption.

Our second two datasets are both tax revenue data. We acquired alcohol tax revenue records from the Colorado Department of Revenue, dating back to 2004, which is disaggregated into beer, wine, and liquor. We added Colorado marijuana revenue, also published by the Colorado Department of Revenue, and the total number of marijuana retail stores to complete this dataset.

Our third and final dataset is Washington's beer revenue from 2010 through 2015. This data is provided by the Washington Department of Revenue, and we also added the state's marijuana revenue from the same source to complete the data.

Methodology

To analyze the effects of marijuana legalization on alcohol consumption in the BRFSS data, we first needed to aggregate the yearly files, drop irrelevant variables, and generate various measures of alcohol consumption and demographic information that contained values for each year's data. Often, the subjects are not asked the same questions each year, or the variable names are different, so we had to generate both dummy and continuous variables with values for each year.

We generated a dummy variable named *binge*, which equals 1 if the interviewee admitted to having binge drank in the last 30 days and 0 if they had not. Binge drinking is defined as consuming five or more alcoholic beverages in one drinking occasion. We also generated a dummy variable *anydrink* that equals 1 if the respondent admitted to having any alcoholic drinks in the last 30 days and 0 if they had not. We generated the variable *drinksmonth*, which is the total number of alcoholic drinks the subject consumed in the past 30 days, and *avgdrinks*, which is the average number of alcoholic drinks per drinking occasion. In addition to the measures of alcohol consumption, we generated dummy variables that indicate whether or not marijuana supply and demand were legal in that particular state at the time of the interview. *Demandlegal* equals 1 if the interview date is after November 6, 2012 and the subject lives in Colorado, or if the interview date is after December 9, 2012 and the subject lives in Washington—these are the dates on which marijuana possession was legalized in the respective state. This variable equals 0

if the interview took place before these dates, or if the subject lives in any state other than Colorado or Washington. *Supplylegal* follows the same logic, and equals 1 if the date was after January 1, 2014 in Colorado or July 8, 2014 in Washington. These dummy variables are our key variables of interest, as their coefficients will indicate the effects of legalization on alcohol consumption.

We also generate dummy variables to control for urban vs. rural counties, smoking status, relationship status, income level, education level, age, race, pregnancy status, as well as fixed state and year effects. These control variables capture the effect of each variable on different measures of alcohol consumption, which make the coefficients and standard errors on our variables of interest more precise. By adding these variables to regressions, we reduce the likelihood of suffering from omitted variable bias. We also restrict our dataset to Colorado, Washington, Idaho, Utah, and Montana to analyze the regression discontinuity with a difference in differences model. We include Colorado and Washington because those are the only states that have legalized marijuana with over a year of available data reflecting this change. These two states are the treatment group-- we are interested in seeing how the trends in these states change after treatments (legalizations) compared to the control group, where marijuana is never legalized. The other three states have similar demographic compositions to Washington and Colorado and alcohol consumption trends similarly prior to legalizations. Finally, by including dummy variables for each state and year we can control for the unobservable differences between each state and each year.

For both sets of tax data, we generate the appropriate supply and demand legalization dummy variables, which are again our variables of interest. These variables serve the same purpose for each state, but their values are obviously different, as supply and demand

legalizations occurred on different dates in each state. We add several state-specific macroeconomic controls that could influence alcohol tax revenue in any given year, particularly in the case of a recession: unemployment, minimum wage, consumer price index, and population. We add month dummy variables to control for the seasonality of alcohol sales and, as previously mentioned, the number of retail marijuana stores and total marijuana tax revenue. The macroeconomic indicators and month dummy variables are the control variables for these data sets. In the both data sets, we also look at the natural log of revenue to see how marijuana legalization affects sales in percentages.

Lastly, we generate several graphs to more clearly illustrate the trends in alcohol and marijuana revenue. We want to show how the trends in alcohol revenue for both states change when marijuana is legalized and how alcohol revenue trends compared to marijuana revenue.

Empirical Specifications

We use Poisson regressions to analyze the effects of marijuana legalization on the number of drinks consumed per month and on average drinks per drinking occasion. Poisson regressions are used to effectively analyze count variables with a low expected value. One advantage of Poisson regressions is that you interpret coefficients as percentages, similar to natural logs. The difference is that these regressions, which look for maximum likelihood and a derivative equal to zero through many iterations, work when the value is 0—natural logs do not. To use a Poisson regression, we must know the expected value of our variable, and the occurrences must be independent of each other. The likelihood of another event occurring cannot be influenced by the occurrence of the last. *Drinksmonth* has a known average value and, while on a daily basis consuming an alcoholic drink may influence the consumption of another, this variable is retrospective and counts total drinks over the last month. Over the course of a

month, we can assume that drinks are consumed relatively independently of each other. *Avgdrinks* also satisfies this criteria because each individual is observed only once-- the average number of drinks for one individual should not influence the average drinks for another. We run four different regressions for each dependent variable. The first contains no controls and isolates the effects of supply and demand legalizations on drinks in the last 30 days.

$$\text{drinksmonth} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + u_i$$

$$\text{avgdrinks} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + u_i$$

The second contains the aforementioned demographic controls, which will make our estimates more precise. The third regression includes the same demographic controls as well as the controls for the fixed state and year effects, but the sample contains respondents from every state. The fourth, and most relevant regression, is our diff in diff model, which includes all of the controls and is restricted to Colorado, Washington, Utah, Idaho, and Montana.

$$\text{drinksmonth} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{controls} + u_i$$

$$\text{avgdrinks} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{controls} + u_i$$

These Poisson regressions will illustrate the effect of marijuana supply and demand legalization on individuals' total drinks in the last 30 days, and their average number of drinks per drinking occasion.

We used Ordinary Least Squares (OLS) with heteroskedastic robust standard errors to analyze the effects of legalizations on whether or not individuals binge drank or drank at all in the last 30 days. OLS is effective when using binary dependent variables, and its interpretation is more straightforward than Poisson regressions on binary variables. We used heteroskedastic robust standard errors to control for heteroskedasticity in the disturbance term. OLS assumes homoskedasticity-- that the variance of each disturbance term is the same across all

observations. Using heteroskedastic robust standard errors allows us to fit a model in the presence of heteroskedasticity. We also run both of these regressions four times, following the same specifications as before: no controls, demographic controls, demographic controls and fixed effects, all controls in the diff in diff model.

$$\text{binge} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{controls} + u_i$$

$$\text{anydrink} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{controls} + u_i$$

As previously mentioned, the demographic controls for each of the four BRFSS regressions are whether or not the individual lives in an urban county, his or her smoking status, relationship status, income level, education level, age, race, and pregnancy status. The fixed state and year effects control for unobserved differences between years and states.

For the Colorado tax data, we run regressions with Newey-West Standard errors. These standard errors help to overcome autocorrelation in the residuals. It is likely that a given month's tax revenue is correlated with the revenue of the months preceding it, so we used Newey-West standard errors and controlled for three lags. We also generate a table with four slightly different models. First we don't include any controls, to isolate the effects of legalizations on revenue. We do, however, include a lagged value of the relevant revenue to control for correlation with last month's revenue. Next we include macroeconomic controls. In the third regression we include macroeconomic and monthly controls. In the fourth regression, the dependent variable is the natural log of revenue, which allows us to interpret the effects of legalization in percentage terms. We generate one of these tables for liquor revenue, beer revenue, and wine revenue.

$$\begin{aligned} \text{Lnliquorrev} = & B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{retailstores} + B_4 \text{marijuanarev} \\ & + B_5 \text{lagliquorrev} + B_6 \text{controls} + u_i \end{aligned}$$

This regression allows us to see how possession and retail legalization in Colorado affect the state's liquor revenue in percentage terms.

$$\text{BeerRevenue} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{retailstores} + B_4 \text{marijuanarev} \\ + B_5 \text{lagbeerrev} + B_6 \text{controls} + u_i$$

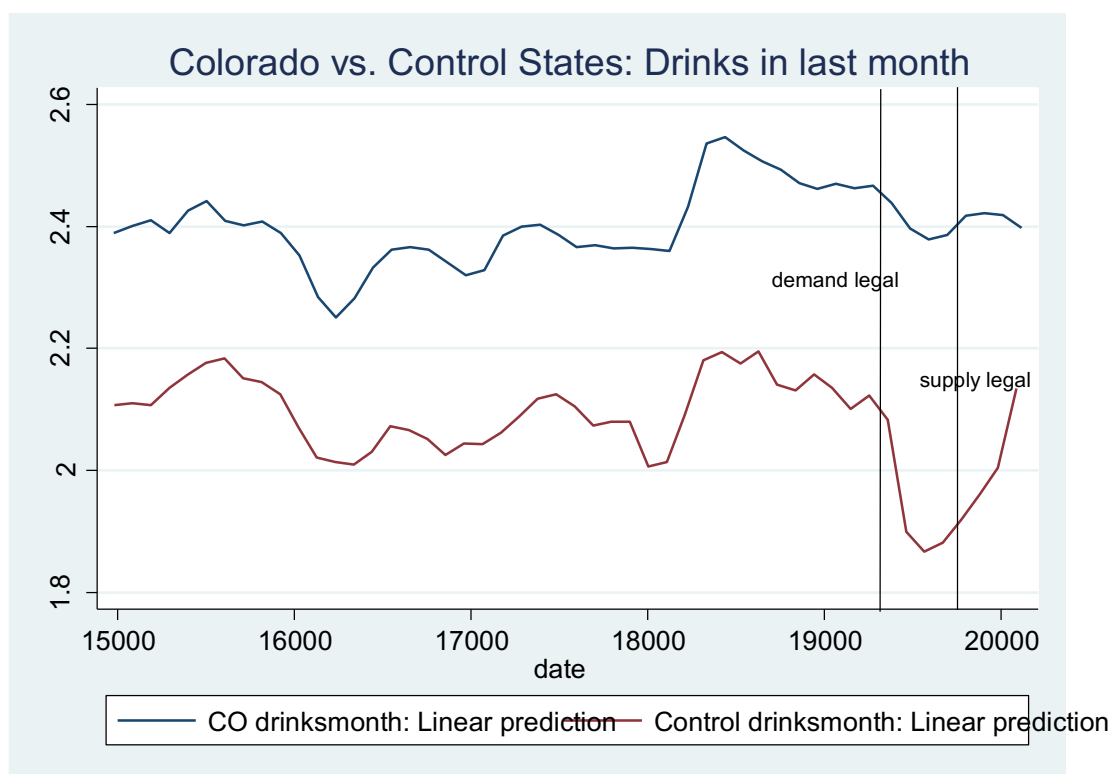
The intuition behind this regression is the same, but we instead look at the effect of legalizations in terms of dollars, not percentages. We analyzed Washington's tax revenue in a similar way:

$$\text{BeerRevenue} = B_0 + B_1 \text{supplylegal} + B_2 \text{demandlegal} + B_3 \text{marijuanarev} + B_4 \text{lagbeerrev} \\ + B_5 \text{taxhike} + B_6 \text{controls} + u_i$$

Washington nearly tripled its beer tax in June 2010, which was eventually lowered to the original level in July 2013 in anticipation of marijuana's legalization. The increased tax rate is very evident in the data, so we created a dummy variable, *taxhike*, to control for the heightened revenue during this three year period. Despite controlling for the tax hike, we expect the three year period of heightened revenue to make the coefficient estimates on our variables of interest noisy. Washington privatized its state-controlled liquor market in 2012, which actually increased liquor prices across the state. This market shift would further complicate our revenue analysis, but we do not have access to liquor revenue and will therefore not consider liquor sales in Washington. We will look exclusively at beer and wine revenue.

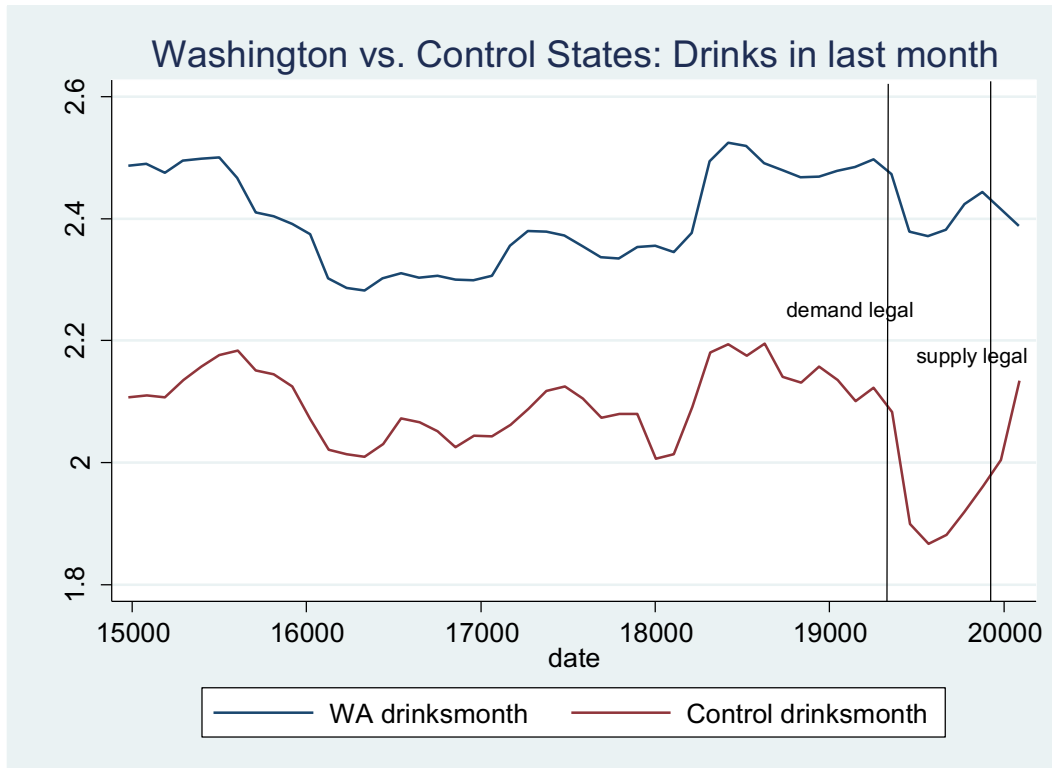
Results & Analysis

Analysis of the BRFSS data yielded results that both support and contradict our original hypothesis in different ways. Our first Poisson regressions, which analyze the effects of legalizations on the number of drinks the individual consumed in the last month indicate that the legalization of marijuana supply has a small, but significant effect on drinks per month in our diff in diff model. First we will look at the relationship graphically. The following graph shows the average drinks consumed in the last 30 days for citizens of Colorado compared to the control group, with time on the x-axis:



The values here are far less important than the trends: We see that prior to either legalization, Colorado trends relatively parallel to the control group. Following supply legalization, alcohol consumption in Colorado starts to fall while the consumption in the control states increases. This

is a visual representation of what our regressions tell us. The same graph that plots Washington against the controls tells the same story:



Following retail legalization, alcohol consumption trends down in Washington, while consumption in the control states rises. The following table illustrates this relationship numerically and includes both Colorado and Washington, and is restricted to the diff in diff model in column 4.

Total Alcoholic Drinks in last 30 Days

Poisson Regressions

	(1) drinksmonth	(2) drinksmonth	(3) drinksmonth	(4) drinksmonth
drinksmonth supplylegal	0.0000224 (0.993)	0.0320*** (0.000)	0.0340*** (0.000)	-0.0184*** (0.000)
demandlegal	0.186*** (0.000)	0.0814*** (0.000)	0.00823*** (0.000)	0.0317*** (0.000)
<i>N</i>	5229997	3176213	3176213	436721
<i>demographic controls</i>		Yes	Yes	Yes
<i>fixed state and year controls</i>			Yes	Yes
<i>Model restricted to CO, WA, UT, MT, ID</i>				Yes

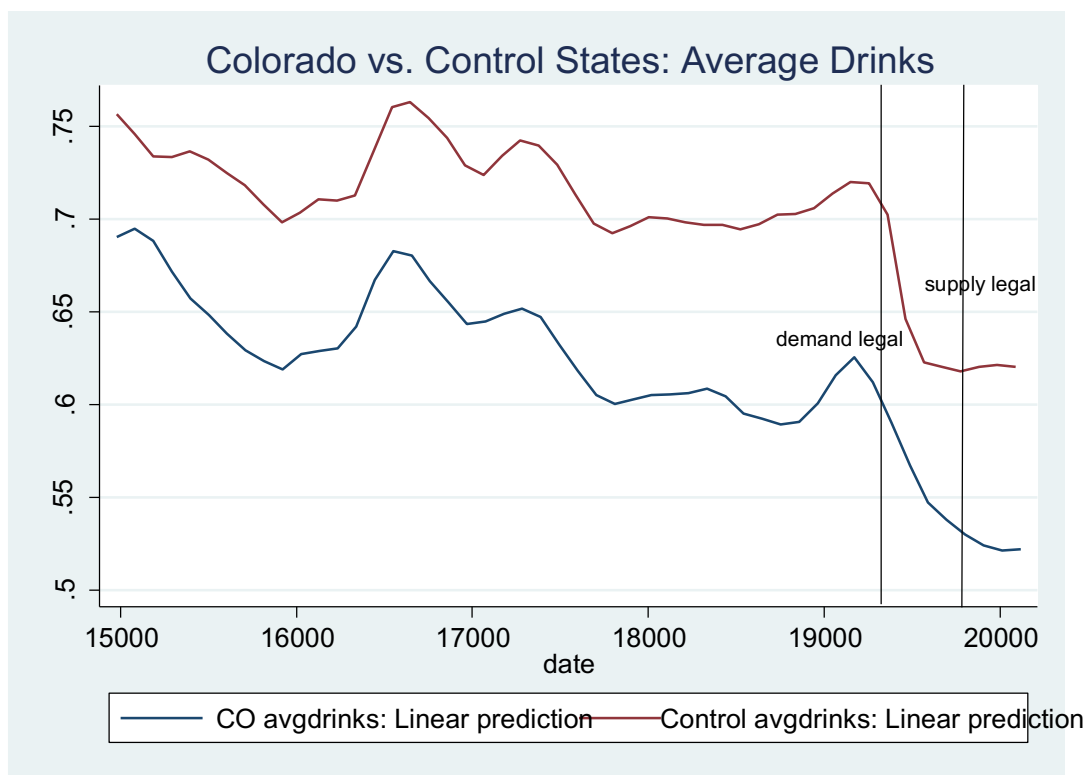
p-values in parentheses

* *p* < .1, ** *p* < .05, *** *p* < .01

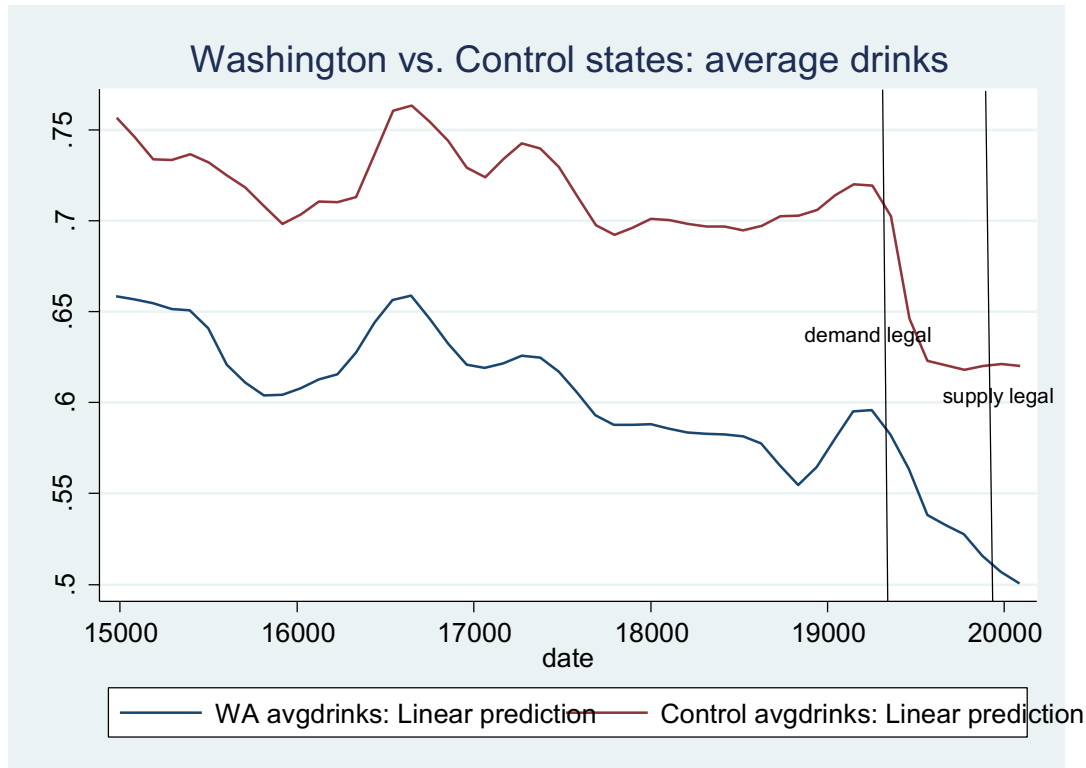
The coefficient b1 in column 4 suggests that the legalization of retail marijuana in Colorado and Washington reduces the average number of alcoholic drinks an individual consumes per month by 1.84 percentage points. The mean drinks per month for individuals in our model, which is restricted to residents of Colorado, Washington, Utah, Montana, and Idaho, is 11.05. The model suggests that an individual who consumed 10 alcoholic drinks per month, for example, prior to the legalization of retail marijuana, would reduce his or her consumption of alcoholic beverages to 9.82 per month after supply legalization. With a *p*-value of 0, this coefficient is significant at the one percent level. This evidence of the substitution effect supports the hypothesis that the legalization of marijuana supply will have a small but significant negative effect on alcohol consumption.

The legalization of marijuana possession, however, seems to have the opposite effect. The model suggests that legalization of marijuana demand increases drinks per month by 3.1 percentage points. Using the same example, this suggests that an individual who consumed 10 drinks per month prior to demand legalization would increase her or her consumption of alcoholic beverages to 10.31 after legalization. This coefficient, which is also significant at the one percent level, contradicts our original hypothesis because it suggests that marijuana legalization has a small but significant positive effect on alcohol consumption. This is apparent in the previous graphs, as alcohol consumption decreases more in the control states than the treatment states following demand legalizations.

The effects of legalizations on average drinks per drinking occasion produce similar results.



Similar to *drinksmonth*, *avgdrinks* trends slightly downwards in Colorado and slightly upwards in the control states following retail legalization. Washington's data tells a similar story:



Clearly, more data post-treatment is necessary to fully understand these trends, but even our small sample shows that alcohol consumption trends downwards relative to the control group following supply legalization. The following regression table expresses this relationship numerically:

Average Drinks per Drinking Occasion

Poisson Regressions

	(1) avgdrinks	(2) avgdrinks	(3) avgdrinks	(4) avgdrinks
avgdrinks				
supplylegal	-0.0320*** (0.000)	-0.0123 (0.335)	-0.0174 (0.189)	-0.0208 (0.259)
demandlegal	-0.111*** (0.000)	-0.0488*** (0.000)	0.0265*** (0.001)	0.0161 (0.185)
<i>N</i>	2575448	1674755	1674755	230830
<i>Demographic controls</i>		Yes	Yes	Yes
<i>Fixed state and year controls</i>			Yes	Yes
<i>Model restricted to CO, WA, UT, MT, ID</i>				Yes

p-values in parentheses

* *p* < .1, ** *p* < .05, *** *p* < .01

The coefficient b1 in column 4 suggests that supply legalization decreases average drinks by 2 percentage points. Someone who drinks 3 alcoholic drinks before retail legalization, for example, would drink 2.94 drinks per occasion after legalization (The mean of *avgdrinks* is 2.04). The *p*-value of this coefficient is 0.259, meaning it is not significant at any relevant significance level. The 95 percent confidence interval for b1 ranges from -0.056 to 0.015. Similar to drinks per month, demand legalization increases the number of average drinks by 1.6 percentage points. The *p*-value on b2 is lower than that of b1, but it is still greater than 0.1, meaning it is not significant at the ten percent level. Despite the statistical insignificance, this regression suggests the same thing as the first: demand legalization very slightly increases alcohol consumption, while supply legalization very slightly decreases it.

The BRFSS regressions on binary drinking variables yield similar results.

Probability of Drinking any Alcoholic Beverage in Last 30 Days

OLS, Robust Standard Errors

	(1) anydrink	(2) anydrink	(3) anydrink	(4) anydrink
supplylegal	0.00153 (0.742)	-0.00319 (0.598)	-0.00563 (0.488)	-0.00563 (0.488)
demandlegal	0.101 ^{***} (0.000)	0.0711 ^{***} (0.000)	0.0184 ^{***} (0.000)	0.0184 ^{***} (0.000)
<i>N</i>	617021	432699	432699	432699
<i>Demographic controls</i>		Yes	Yes	Yes
<i>Fixed state and year controls</i>			Yes	Yes
<i>Model restricted to CO, WA, UT, MT, ID</i>				Yes

p-values in parentheses* *p* < .1, ** *p* < .05, *** *p* < .01

The coefficient b2 is 0.018 and has a p-value of 0, meaning it is significant at the 1 percent level.

This means that demand legalization increases the probability that an individual had at least one alcoholic drink in the last month by 0.019. This, again, is very small but significant evidence that following possession legalization, marijuana and alcohol are treated as complements, which contradicts our hypothesis.

Using our binary variable for binge drinking as the dependent variable, demand legalization appears to have a strong effect on the incidence of binge drinking.

Probability of Binge Drinking

OLS, robust standard errors

	(1) binge	(2) binge	(3) binge	(4) binge
supplylegal	-0.000759 (0.872)	-0.00630 (0.314)	-0.00339 (0.600)	0.00543 (0.513)
demandlegal	0.276*** (0.000)	0.278*** (0.000)	0.0539*** (0.000)	0.119*** (0.000)
<i>N</i>	4713887	2828311	2828311	381880
<i>Demographic controls</i>		Yes	Yes	Yes
<i>Fixed state and year controls</i>			Yes	Yes
<i>Model restricted to CO, WA, UT, MT, ID</i>				Yes

p-values in parentheses* *p* < .1, ** *p* < .05, *** *p* < .01

We consider b1 to be negligible in column 4, as it is near 0 with a large *p*-value. B2, however, is significant and has a powerful implication. It says that demand legalization increases the probability of an individual binge drinking by 0.119. The mean of the variable is 0.245, meaning if we select an individual at random, there is at 24.5% chance that he or she binge drank in the last 30 days (remember: binge drinking is defined as drinking 5 or more drinks on one occasion). This model suggests that the legalization of marijuana possession increases the chance that an individual binge drinks by 11.9%. This is strong evidence that marijuana and alcohol are treated as complements, not substitutes.

Analysis of the BRFSS data reveals very minor evidence of the substitution effect between marijuana and alcohol following supply legalization, and it showed more substantial evidence of the complementary effect between the two substances following demand legalization. More years of post-treatment data are needed to more accurately quantify the

effects of marijuana legalization on alcohol consumption. Analysis of Colorado's tax revenue reveals only evidence of the substitution effect.

Colorado Liquor Revenue

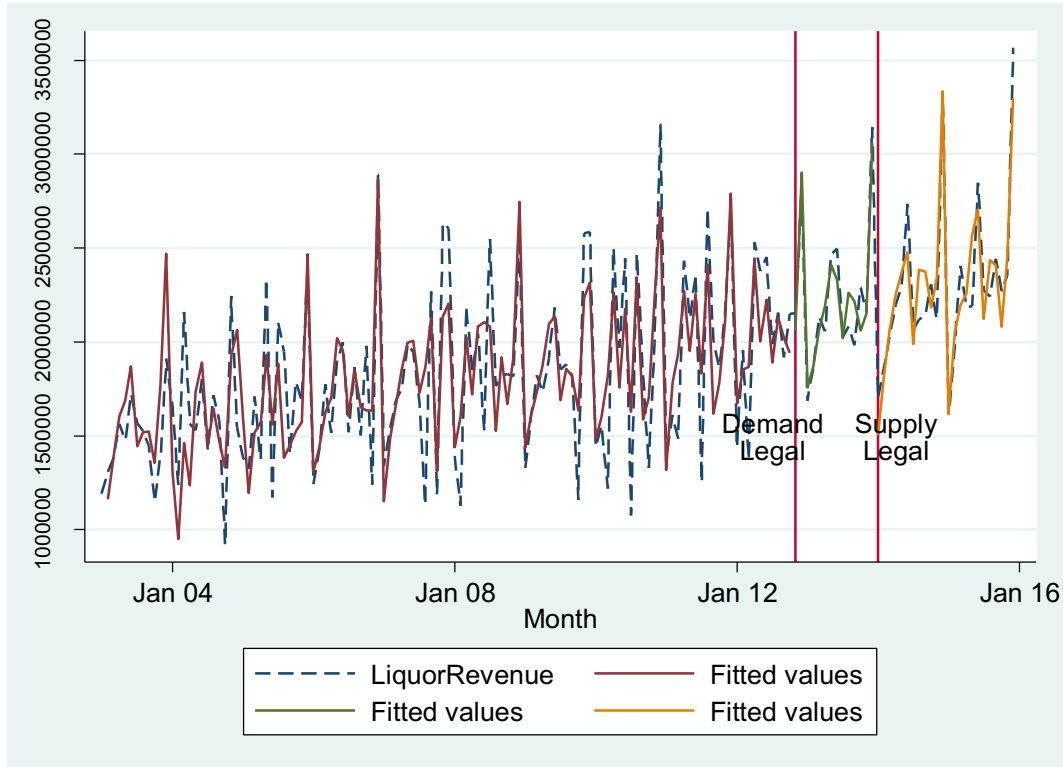
OLS, Newey-West Standard Errors

	(1) LiquorRevenue	(2) LiquorRevenue	(3) LiquorRevenue	(4) lnliquorrev
SupplyLegal	-520127.7* (0.073)	-1220855.4*** (0.000)	-520133.3** (0.028)	-0.180 (0.134)
DemandLegal	487765.5*** (0.000)	118022.1 (0.361)	-5165.0 (0.939)	-0.000570 (0.988)
<i>N</i>	155	155	155	155
<i>Macroeconomic controls</i>		Yes	Yes	Yes
<i>Monthly controls</i>			Yes	Yes

p-values in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

The coefficient b1 in column 3 suggests that supply legalization decreases monthly liquor revenue in Colorado by \$520,133, which is significant at the 5 percent level. Colorado's mean monthly liquor revenue is \$1,918,290, so this decrease is very substantial and significant evidence that recreational marijuana is treated as a substitute to alcohol. The coefficient b1 in column 4 says that legalization decreases liquor revenue by 18%. The p-value of 0.134 means it is not significant at the ten percent level. That being said, the large absolute value of b1 and its relatively low p-value suggest that there is a strong substitution effect at play, as observed in the previous regression. The p-value on b2 in both columns 3 and 4 is extremely high, so we will disregard these values. The following chart shows how Colorado's liquor revenue trends over time.



The actual revenue is shown with the dashed line and the solid lines are the lines of best fit produced by our model for each of the three segments of time: before demand legalization, between demand and supply legalization, and after supply legalization. While liquor revenue continues to rise after supply legalization, it has been trending upwards over time, and this trend slows significantly when retail marijuana shops opened on January 1, 2014.

The results are similar for beer revenue, though p-values are higher and the estimates are noisier.

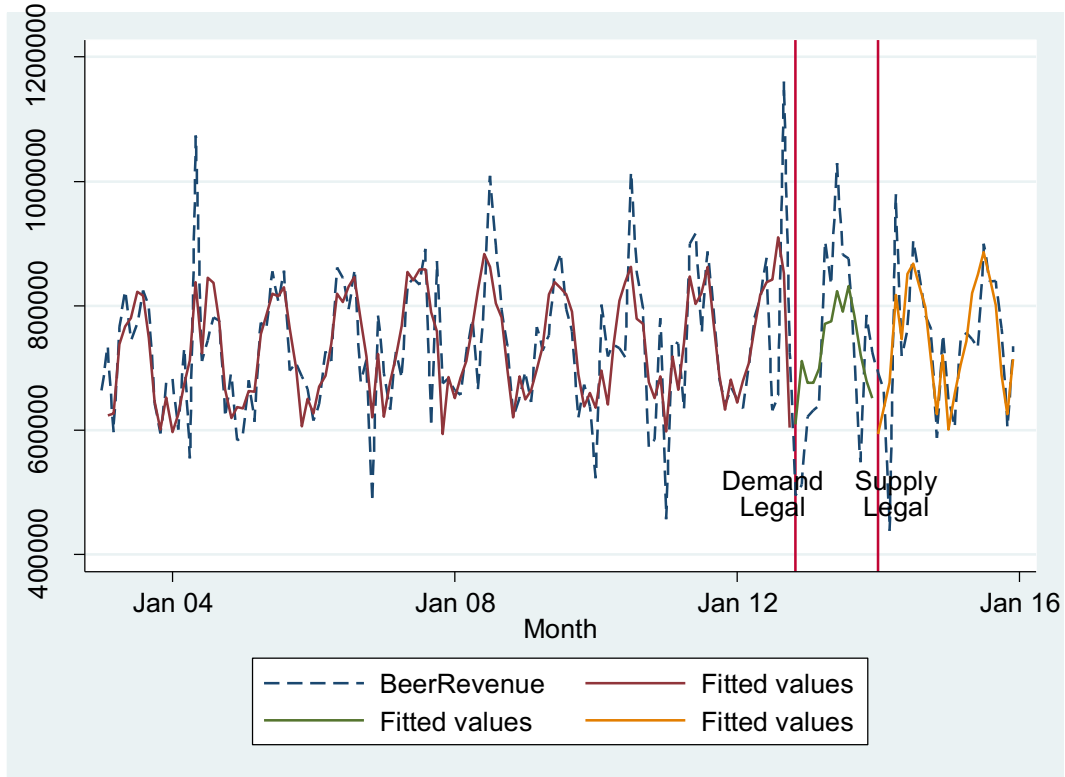
Colorado Beer Revenue
OLS, Newey-West Standard Errors

	(1)	(2)	(3)	(4)
	BeerRevenue	BeerRevenue	BeerRevenue	lnbeerrev
SupplyLegal	130463.4 (0.184)	48930.7 (0.625)	-71096.2 (0.365)	-0.124 (0.299)
DemandLegal	-5662.7 (0.917)	-40537.5 (0.558)	-29144.2 (0.599)	-0.0469 (0.539)
<i>N</i>	155	155	155	155
<i>Macroeconomic controls</i>		Yes	Yes	Yes
<i>Monthly controls</i>			Yes	Yes

p-values in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

The output suggests that supply legalization decreases monthly beer revenue by \$71,096 and 12.4%. The mean monthly beer revenue is \$735,313. The *p*-value on each *b1* estimate is greater than 0.1, meaning they are not significant at the ten percent level, and the standard errors are very high. *B2* suggests that demand legalization also decreases beer revenue, though the magnitude is lower and the *p*-value is higher. Despite the statistical insignificance, this output suggests that marijuana legalization decreases alcohol sales-- evidence of the substitution effect. The following graph shows how Colorado beer revenue trends with time, and trend lines are unique for each of the three time segments.



It is apparent that following demand and supply legalizations, the trend lines shift down. These trend lines are, however, comprised of noisy estimates. The raw beer revenue also appears to trend downwards following legalizations.

We ran the same regressions with wine revenue and the natural log of wine revenue as the dependent variables.

Colorado Wine Revenue
OLS, Newey-West Standard Errors

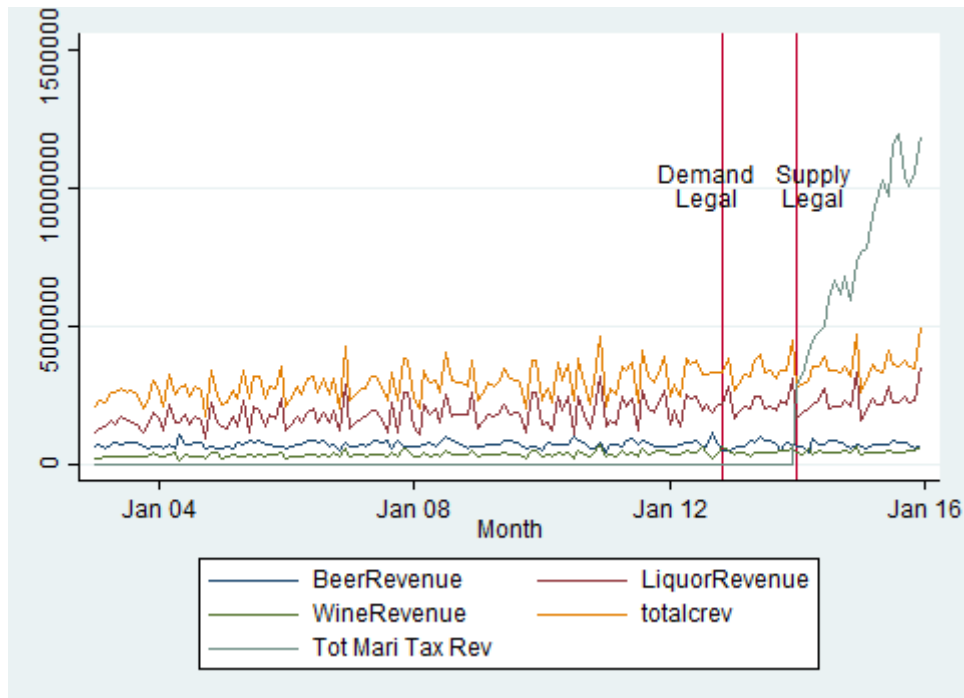
	(1)	(2)	(3)	(4)
	WineRevenue	WineRevenue	WineRevenue	lnwinerev
SupplyLegal	-91217.5** (0.045)	-225136.4*** (0.001)	-37823.0 (0.484)	-0.0336 (0.798)
DemandLegal	99949.6*** (0.001)	30708.1 (0.492)	-1800.1 (0.956)	-0.0198 (0.798)
<i>N</i>	155	155	155	155
<i>Macroeconomic controls</i>		Yes	Yes	Yes
<i>Monthly controls</i>			Yes	Yes

p-values in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

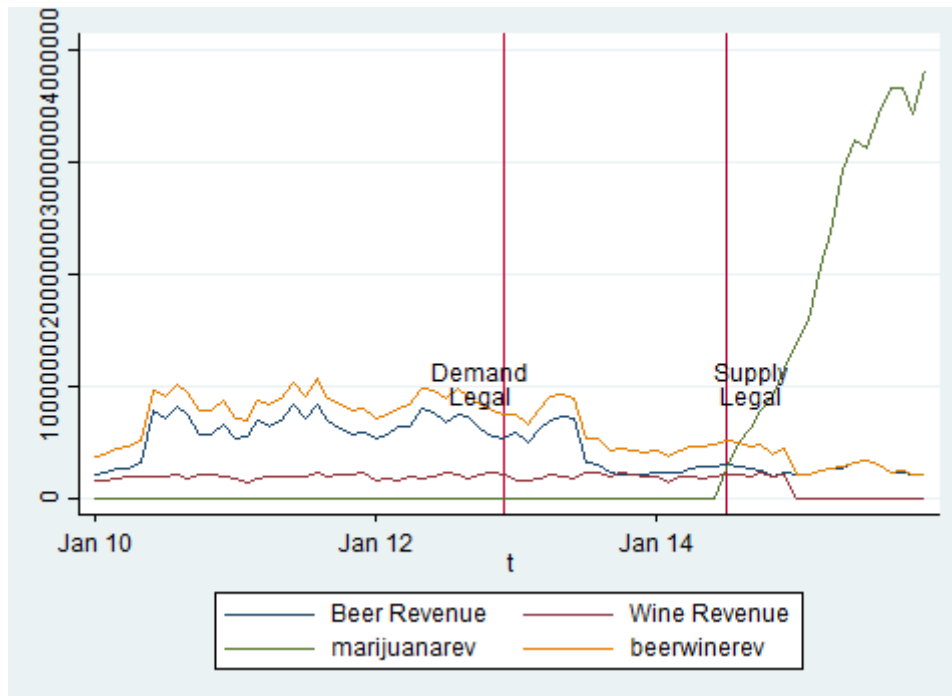
As a result of the very high *p*-values and large standard errors, we will exclude these regressions from our analysis.

To put the effects of legalization on alcohol sales in perspective, the following chart superimposes beer revenue, liquor revenue, wine revenue, and total alcohol revenue (a sum of the previous three) on marijuana tax revenue.



While marijuana legalization, particularly supply legalization, decreased revenue from alcohol sales, marijuana sales generate substantially more revenue than all alcohol sales combined. It is also important to note that this massive stream of revenue from marijuana sales is due partly to tourism. Colorado was the first state to legalize recreational marijuana, and it has developed a very profitable marijuana tourism industry as a result. From a revenue perspective, the alcohol sales that are cannibalized by marijuana sales are nearly negligible. The results are more significant when analyzed from a behavioral economics perspective: the legality of recreational marijuana causes some people to consume more marijuana and less alcohol.

Results from the Washington tax data are less conclusive, due in part to the smaller sample of data and the three year rise in the beer tax, which we previously mentioned. Before looking at the effects of legalization on beer and wine revenue, the following graph illustrates the problem with this data.



Marijuanarev is total marijuana revenue and *beerwinerev* is the sum of beer and wine revenue for each month. Data on liquor revenue was not available. It is evident that the dramatic rise and fall of beer revenue took place independently of marijuana legalization, though beer and wine revenue continue their downward trajectory following the tax cut.

Washington raised its beer tax dramatically between June 2010 and July 2013, and the revenue spike is very apparent in the data. Due to the dramatic revenue decrease in July 2013, between demand and supply legalizations, it is difficult to isolate the effect of these legalizations on beer revenue.

Washington Beer Revenue
OLS with Newey-West Standard Errors

	(1)	(2)	(3)	(4)
	BeerRevenue	BeerRevenue	BeerRevenue	lnbeerrev
supplylegal	107259.8 (0.605)	88448.4 (0.652)	285604.2 (0.192)	0.0364 (0.156)
demandlegal	-288548.6 (0.283)	-368238.6 (0.471)	100840.7 (0.730)	-0.0435 (0.132)
taxhike	2902574.0*** (0.000)	3196828.7*** (0.000)	3781068.9*** (0.000)	0.900*** (0.000)
<i>N</i>	71	71	71	71
<i>Macroeconomic controls</i>		Yes	Yes	Yes
<i>Monthly controls</i>			Yes	Yes

p-values in parentheses

* *p* < .1, ** *p* < .05, *** *p* < .01

Washington never raised its wine tax, so the effect of marijuana legalizations on wine revenue may be less noisy.

Washington Wine Revenue
OLS, Newey-West Standard Errors

	(1)	(2)	(3)	(4)
	WineRevenue	WineRevenue	WineRevenue	lnwinerev
supplylegal	20622.4 (0.944)	-70111.4 (0.780)	-27612.4 (0.892)	-0.329 (0.465)
demandlegal	-30371.3 (0.647)	-270163.6 (0.152)	-125948.5 (0.276)	-0.437 (0.111)
taxhike	-34064.5 (0.626)	74593.2 (0.644)	98753.7 (0.352)	0.295 (0.209)
<i>N</i>	71	71	71	71
<i>Macroeconomic controls</i>		Yes	Yes	Yes
<i>Monthly controls</i>			Yes	Yes

p-values in parentheses

* *p* < .1, ** *p* < .05, *** *p* < .01

In terms of both dollars and percentage change, both supply and demand legalizations have strong negative effects on wine revenue in Washington. None of the *p*-values are significant at the ten percent level, but the very large negative value on each coefficient suggest that the substitution effect is at play in Washington between marijuana and wine. Our model suggests that supply legalization decreases wine revenue by 32.9% and demand legalization decreases it by 43.7%. Again, neither of these changes is statistically significant.

Conclusion

Our results were somewhat mixed-- some regressions supported the complementary hypothesis, some supported the substitution hypothesis, and some results were statistically insignificant. In particular, the BRFSS needs more years of post-legalization data to provide a better picture of what is happening to alcohol sales in Washington and Colorado. Even so, the statistically significant results from the BRFSS data provide evidence that possession legalization slightly increases alcohol consumption, but that retail legalization slightly decreases drinking habits. The complementary effect is strongest in the case of binge drinking, which provides further evidence to support a hypothesis that Wen, Hockenberry and Cummings (2015) introduce in the conclusion of their paper. They suggest that marijuana and binge drinking are complements because people who binge drink may be seeking the most dramatic change in their mental state, and would be likely to use marijuana to heighten this. Our model supports this hypothesis by suggesting that legal marijuana possession significantly increases the probability that an individual will binge drink. We also found that legal retail marijuana slightly but significantly reduces the number of drinks per month, which supports our substitution hypothesis. The tax data from Colorado provides strong evidence in support of our substitution hypothesis, though the effect is larger for liquor than beer, which contradicts our initial belief that marijuana legalization would cannibalize beer sales more than liquor and wine sales. Though results from Washington tax data are a bit noisy, evidence from wine revenue once again provides strong evidence in support of the substitution hypothesis. A point to consider is the impact of tourism in Colorado and Washington. The legalization of marijuana may have increased tourism to these states, and tourists would also consume alcohol in the state. In fact, according to the Denver Post, tourism in Colorado set an all time record in 2014, the first year of

legalization there. In this case, the estimates of decreasing alcohol use would be understated, and our results would be biased downwards. However, though Colorado now has a thriving weed industry, there is no evidence its tourism spike is due to this. 2014 was the fourth year in a row that tourism in the state had increased, and when polled, more tourists said the marijuana laws were a disincentive rather than incentive. While our results were mixed and differed significantly between data sets, our study supports the notion that marijuana and alcohol may be treated differently in different contexts. As a whole, our study suggests that marijuana legalization slightly but significantly reduces alcohol consumption, and that the substances are treated as substitutes.

As previously stated, this finding is important because the relationship between the substances is of relevance to policymakers and the general public. Proponents of marijuana legalization typically indicate increased tax revenue as a major benefit. While our results indicate that marijuana legalization decreases alcohol revenue in Colorado and Washington, it is important to recognize that marijuana revenue does more than enough to compensate for this difference. Only on a monthly basis, marijuana generates far more revenue than total alcohol sales in both states. This revenue is typically put towards public education and social programs, which contributes to general societal well being. The social effects are more complicated. It can be assumed that a decrease in alcohol consumption is good for society, though comparing these effects to the effects of increased marijuana usage is subject for another debate. Socially speaking, the substitute theory is a better situation than the complements model, where both would increase. However, it is also important to consider the potential complementary relationship between binge drinking and marijuana use. Binge drinking is a dangerous form of alcohol consumption, and it is associated with many health and social problems. The

implications of a complementary relationship between binge drinking and marijuana use may actually be more socially relevant than the one concerning any kind of drinking. In this case, legalization may do more damage than good.

More research on this subject is needed to determine the true relationship between the substances, which may prove to vary contextually. As more states legalize marijuana, and more time passes since legalization, this relationship can be more precisely defined and analyzed. Though there have been previous studies on this topic, the available data has been limited due to the federally illegal status of marijuana. Even in this study, data is limited because recreational marijuana became legal in 2014 and most data is only available through 2015. The Federal government still has not legalized marijuana, so any Federal survey data, such as the BRFSS, will not ask casual questions about marijuana use, and even if they did we could not assume the answers would be truthful. In the future, we can use data from Colorado, Washington, Oregon, Alaska, the District of Columbia and any other state that legalizes marijuana use. In time, this data will be more comprehensive than what is currently available. Ideally, as legalization becomes more universal, federal surveys such as the BRFSS will ask questions about marijuana use in order to investigate this relationship. For the time being, however, researchers must be creative in their methods.

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