Is Medical Marijuana a Gateway Drug?: The Effect of Medical Marijuana Legalization on Heroin Use Rates[!]

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Is Medical Marijuana a Gateway Drug?: The Effect of Medical Marijuana Legalization on Heroin Use Rates[*]

Abstract: The United States is presently going through two substantial changes as it relates to drug use—more states are legalizing marijuana for the purposes of medical treatment and prescription opioid abuse is on the rise, resulting in heroin use rates nearly quadrupling over the past fifteen years. Historically, marijuana has been viewed as a gateway drug. Recent research suggests that medical marijuana legalization has decreased incidence of prescription and other opioid use and overdose. Examining heroin use data and other control variables, we test the effect of medical marijuana legalization on heroin use to determine whether medical marijuana is a gateway drug or substitute for heroin. We find that medical marijuana legalization has a generally negative, but statistically insignificant effect on heroin use rates. This suggests that while the legalization of medical marijuana will not lead to a reduction in heroin use, medical marijuana is not a gateway drug for heroin.

JEL: I18, H75, C23, K32

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1.   Introduction

For many states, the process to legalize medical marijuana has been a tumultuous one. Medical marijuana referendum and legalization measures have not always been embraced, particularly by the federal government. During the mid-1990s and early 2000s, many legalization efforts were vetoed and directly combated by the federal government. In fact, many still oppose such legislation on the grounds that it undermines federal law and concern that marijuana is a "gateway drug." The idea that marijuana, specifically medical marijuana, is a gateway drug has been a prevalent argument against the legalization of medical marijuana. General Barry McCaffrey, Director of the Office of National Drug Policy from 1996-2001 (better known to the public as President Clinton's 'Drug Czar'), was one of the most vocal government officials against the first attempts by states to legalize medical marijuana, often citing the gateway effects of marijuana in his arguments.

In Congressional hearings on state-level medical marijuana initiatives, McCaffrey made several statements on marijuana as a gateway drug: "Marijuana is a 'gateway' drug… the younger an individual uses any gateway drug, the more often an individual uses any gateway drug, the more gateway drugs an individual uses, the likelier that individual is to experiment with cocaine, heroin, and other illicit drugs and the likelier that individual is to become a regular adult drug user and addict."[1] When discussing the message that medical marijuana legalization sends to children, McCaffrey stated, "Referenda that tell our children that marijuana is a 'medicine' send them the wrong signal about the dangers of illegal drugs-increasing the likelihood that more children will turn to drugs. Moreover, marijuana is a 'gateway' drug, leading children into more harmful drug use and eventually addictions."[2] He continues, "The danger of sending the wrong message to our children about marijuana is compounded by the fact that smoking marijuana can often be the first step down a slippery path that leads to the use of drugs like cocaine, heroin, LSD, and methamphetamine… All of us should understand that anything that directly or

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[1] *Prescription for Addiction? The Arizona and California Medical Drug Use Initiatives: Hearings before the Committee on the Judiciary*. 104th Congress, 2nd session, December 2, 1996 (statement by Gen. Barry McCaffrey, Director of the Office of National Drug Policy), pp. 14-16.
[2] *Medical Marijuana Referenda Movement in America: Hearing before the Subcommittee on Crime of the Committee on the Judiciary*. 105th Congress, 1st session, October 1, 1997 (statement by Gen. Barry McCaffrey, Director of the Office of National Drug Policy), p. 15.

indirectly causes increased marijuana use by our children also paves the way for increased 'hard' drug use and addiction."[3,4]

Concerns about the gateway effect of marijuana did not stop in the 1990s, and they have persisted well into the medical marijuana legalization debates of the 2000s. Such arguments have been made by senators[5], attorney generals[6], and state representatives[7] regarding state-level medical marijuana legalization.

Despite these gateway arguments, public opinion towards the use of medical and recreational marijuana has grown more favorable. Gallup poll results since 2004 have consistently (with the exception of 2013-2014) shown an increase in the percentage of Americans who are in favor of marijuana legalization—starting with only 34% polling in favor of marijuana legalization in 2004 and ending with 51% in favor of legalization in 2014 (Saad 2014). However, there are still gateway drug arguments made against medical marijuana. As of July 2015, recreational marijuana is legal in five states—Colorado, Washington, Alaska, Oregon, and the District of Columbia. In addition to these five states that have legalized recreational marijuana, twenty-four states (including the District of Columbia) have legalized medical marijuana.

The use of medical marijuana is also gaining traction in the medical literature and community. The National Institute on Drug Abuse, as of January 2014, had 28 active grants researching the therapeutic benefits of cannabis and cannabinoids (National Institute on Drug

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[3] *Ibid*, pp. 16-17.

[4] During the October 1, 1997 hearing, the Subcommittee on Crime Chairman and Rep. Bill McCollum (R-Florida) (1997, 2), Rep. John Conyers (D-Michigan) (1997, 4), Rep. Asa Hutchinson (R-Arkansas) (1997, 8), Rep. George W. Gekas (R-Pennsylvania) (1997, 34), Rep. Sheila Jackson Lee (D-Texas) (1997, 37), Ronald E. Brooks (Chair of the Drug Policy Committee of the California Narcotic Officers' Association) (1997, 93), and Dr. Janet Lapey (Executive Director of the Concerned Citizens for Drug Prevention, Inc.) (1997, 126) all made statements referring to marijuana as a gateway drug and/or comments about the devastating message that medical marijuana legalization would sends to the public and children regarding drug use.

[5] In 2009, Senator Chuck Grassley (R-Iowa) stated that "marijuana is a gateway to higher drugs" when criticizing Attorney General Eric Holder of not continuing medical marijuana raids in California (quoted in Leinward 2009, 3A).

[6] In 2009, New Hampshire Attorney General Kelly Ayotte sent a letter to state legislatures concerning a bill (that was ultimately defeated) to legalize medical marijuana stating, "One of the most harmful consequences of marijuana use is the role it plays in leading to the use of other illegal drugs. Studies have shown that very few young people turn to illegal drugs such as cocaine or heroin without first experimenting with marijuana" (quoted in Drogan 2009).

[7] In 2013, when the Illinois House Bill HB1, a measure to legalize medical marijuana, passed in the House, State Rep. Patricia Bellock (R-Westmont, IL) stated "there are a lot of us that feel this is a gateway drug" in reference to marijuana (quoted in McDermott 2013, A2).

Abuse 2015). The areas of this research include: autoimmune disease; inflammation; pain; psychiatric disorder; seizures; and substance use disorder, withdrawal, and dependence.

Another "illicit" drug has garnered such positive attention in recent years—heroin. Heroin use and overdose rates have sharply increased over the past five years. Between 2000 and 2013, deaths from heroin overdose increased from 0.7 to 2.7 per 100,000 individuals (Rettner 2015). Rettner notes that "the steepest rise occurred between 2010 and 2013, when the rate of death from heroin overdose increased by 37 percent, compared with rising just 6 percent over the decade before." Jones et al. (2015, p. 720) found that "the annual average rate of past-year heroin use in 2011-2013 was 2.6 per 1,000 persons [age 12 years and older]. This rate was significantly higher than the rates for 2002-2004 (1.6) and 2005-2007 (1.8), and represents a 62.5% increase since 2002-2004."

Not only has heroin use been on the rise recently, but prescription opioid abuse has been steadily on the rise over the past decade as well.[8] The Drug Enforcement Administration issued a press release on August 21, 2014 which included the following statement by DEA Administrator Michele Leonhart: "Almost seven million Americans abuse controlled-substance prescription medications, including opioid painkillers, resulting in 22,134 Americans dying in 2011 from overdoses of prescription medications, including 16,651 from narcotic painkillers" (quoted in DEA Public Affairs, 2014). According to the CDC's infographic on "Today's Heroin Epidemic," individuals who are addicted to prescription opioids are 40 times more likely to be addicted to heroin (Center for Disease Control and Prevention 2015). Additionally, the CDC reported, "45% of people who used heroin were also addicted to prescription opioid painkillers." Cicero et al (2014, p. 823) concluded that approximately 75% of opioid analgesic addicts switch to heroin as a cheaper source for their high.

Given the recent trends in these two categories of drug use, a key question emerges: what, if any, is the relationship between medical marijuana legalization and heroin use? There are two competing notions — the gateway effect and the substitution effect. A substantial amount of research empirically examines whether or not marijuana is a gateway drug (DeSimone 1998; Morral et al. 2002; Van Ours 2003; Fergusson and Horwood 2006; Bretteville-Jansen and

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[8] Examples of prescription opioid painkillers/analgesics include (but are not limited to) drugs like oxycodone, hydrocodone, fentanyl, morphine, methadone, hydromorphone, etc.

Jacobi 2011). Many others have specifically analyzed the effects of medical marijuana legalization on policing effectiveness (Adda, McConnell, and Rasul 2014); crime (Morris et al. 2014); traffic fatalities and alcohol use (Anderson, Hansen, and Rees 2014); marijuana use (Cerdá et al. 2012; Pacula et. al. 2015); marijuana, alcohol, and hard drug use (Wen, Hockenberry, and Cummings 2014); and opioid prescription overdose rates (Bachhuber et al. 2014).

We empirically test if the relationship between medical marijuana legalization and heroin use is one of the gateway effect or the substitution effect. Our paper contributes to the literature by clearly articulating the path by which medical marijuana could be a substitute for heroin. The gateway effect is categorized by medical marijuana legalization in the current time period having a positive impact on heroin use in the future. If the idea that marijuana acts as a "gateway drug" is correct, we would expect to see that legalization of medical marijuana would lead to more medical marijuana users. If, over time, the high from medical marijuana use becomes unsatisfactory or is no longer sufficient to gain the user euphoria, the gateway effect would cause these users to start abusing harder and more potent substances in pursuit of a more intense high. The substitution effect would occur when medical marijuana legalization in the present time period leads to a decrease in future heroin use rates. The mechanism by which this substitution takes place is by presenting the medical patient with options beyond prescription opioids. In instances where the patient chooses the medical marijuana treatment over the prescription opioid treatment, the incidence of opioid diversion to non-medical users will necessarily go down, as there is no opioid to divert. As incidents of prescription opioid diversion decreases, there will be fewer opioid users to eventually switch to heroin as a cheaper source to fulfill their addiction. Thus, past medical marijuana could lead to decreases in the likelihood of future heroin use. We further articulate this relationship in Section 2.

Our paper also contributes to the literature by utilizing a new data source for our dependent variable. Many other articles use data from drug arrests, substance abuse facility admittance rates, and/or overdose rates as proxies for drug use. Our dependent variable, the estimated number of people that have ever used heroin, is aggregated from the National Survey on Drug Use and Health (NSDUH), formerly known as the National Household Survey on Drug Abuse (NHSDA), an annual survey sponsored by the Substance Abuse and Mental Health

Services Association (SAMHSA). We accessed the Restricted-Use Data Analysis System (R-DAS) to acquire the 2-year estimates from 2002 to 2013.[9]

We utilize both an ordinary least squares and two-stage least squares, state-level panel data model spanning 2002-2013 to estimate, along with a host of controls, the effect of medical marijuana legalization on heroin use. These models will test for the presence of substitution or gateway effects. Section 2 reviews the relevant literature on the gateway effect attributed to marijuana, as well as articulates how a plausible substitution relationship links medical marijuana and heroin. Section 3 explains the data we use to estimate the effect of medical marijuana legalization on heroin use. Section 4 presents the model and the results, and Section 5 reviews the policy implications and concludes.

2.   Defining the Gateway Effect and Characterizing the Substitution Effect

Twenty-three states and the District of Columbia have legalized medical marijuana, and five states have legalized recreational marijuana use as of July 2015. Colorado had previously passed laws in 2012 and 2013 allowing for possession, consumption, and private cultivation, but it was not until 2014 that commercial sales were permitted. The state of Washington passed Initiative 502 in 2012, but regulations related to sales and possession were unclear for at least a year. In 2015, Alaska and the District of Columbia legalized recreational use and personal possession of one and two-ounces of marijuana, respectively. Alaska has plans to begin retail licensing in 2016, but there are no plans for commercial sales in the District of Columbia. Oregon also passed a measure in 2014 to legalize the possession and consumption of marijuana, and the law went into effect in July 2015. Oregon also has plans to allow for retail marijuana sales in 2016. The medical and recreational marijuana industries have been quite lucrative. For example, in 2014, the state government of Colorado collected $63 million dollars in tax revenue and $13 million in fees and licenses (Ingraham 2015). $386 million in medical marijuana and $313 million in recreational marijuana was sold in Colorado in 2014.

The voting mechanism by which medical marijuana legalization is decided varies by state between a popular or legislative vote. 11 states legalized medical marijuana via popular vote and 13 states legalized medical marijuana by legislative vote. California was the first state to legalize

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[9] As of August 21, 2015, this data is temporarily inaccessible due to changes in SAMHSA's online distributor.

medical marijuana in 1996. Table 1 compiles all of the states with legal medical marijuana (as of July 2015), the voting process, approval date, signage date (if applicable), and effective date.

(insert Table 1 about here)

Marijuana is often cited as a gateway drug. Unsurprisingly, medical marijuana legalization is associated with higher marijuana use (Cerdá et. al. 2012; Wen, Hockenberry, and Cummings 2014). What is less straightforward, and still heavily debated, is the relationship between marijuana use and hard drug use. Some studies find that marijuana use is associated with higher cocaine use (DeSimone 1998; Van Ours 2003) and other hard drug use (Morral et. al. 2002; Fergusson and Horwood 2006; and Bretteville-Jensen and Jacobi 2011). However, the causal mechanism between marijuana use and hard drug use is unclear (DeSimone 1998, p. 150; Fergusson and Horwood 2006, p. 556). Some studies suggest that it is not marijuana use itself that leads to hard drug use in the future, but rather it is the propensity of an individual to use drugs (Morral et. al. 2002, p. 1503) or some unobservable, correlated heterogeneity that makes the individuals more susceptible to marijuana and hard drug use (Van Ours 2003, p. 551).

Although this gateway relationship between marijuana and hard drug is vocalized in political arenas, like those mentioned outlined Section 1, as a reason for keeping marijuana under tight control and illegality, some research suggests that *limited use* of marijuana will not lead to hard drug outcomes and that there might be benefits to treating marijuana differently from hard drugs under the law. Despite his finding that past marijuana use is associated with higher cocaine use in the future, Van Ours (2003) mentions that "allowing controlled use of soft drugs does not have the detrimental effect of stimulating the consumption of hard drugs" (p. 551). From their analysis, Bretteville-Jensen and Jacobi suggest that "a separation of markets for cannabis and hard drugs may prove effective in reducing hard drug uptake if that would reduce the influence of hard drug users and knowledge of those markets might have on current cannabis-only users (2011, p. 1178). Gallet, who estimates the price elasticities of heroin, marijuana, and heroin using a meta-analysis approach, suggests, "[A] 'one size fits all' approach may be inappropriate when designing drug control policy" (2014, p. 65).

There is evidence of medical marijuana legalization and beneficial outcomes. For example, medical marijuana legalization has been associated with reductions in excessive drinking and crime. Anderson, Hansen, and Rees find that medical marijuana legalization is associated with "sharp declines in the price of marijuana and alcohol consumption, which suggests that marijuana and alcohol are substitutes" (p. 333), decreases in vehicle accident fatalities where alcohol was involved (p. 349), and significant declines in binge drinking (p.357).[10] Between 1990-2006, states with legal medical marijuana saw reductions in crime relative to non-MML states, notably homicide, robbery, and aggravated assault (Morris et. al. 2014, p. 4). More broadly, depenalization of cannabis offenses allows police to reallocate time and effort to non-cannabis crime, resulting in reductions of non-drug crime and improvements in policing effectiveness (Adda, McConnell, and Rasul 2014, p. 1184).

Medical marijuana legalization is also associated with reductions in opioid overdose mortality rates, including prescription opioids and heroin. Bachhuber et al. (2014) find that "medical cannabis laws were associated with a mean 24.8% lower annual rate of opioid analgesic overdose deaths… compared with states without laws" (p. 1670). In both groups, states with and without medical cannabis laws, age-adjusted opioid overdose deaths more than doubled during the study period. A major distinguishing factoring, according to Bachhuber et. al. (2014), is that in the final two years for the study (2009-2010), the deaths began to "plateau" in states with medical marijuana laws while the states without medical cannabis laws still increased (p. 1670).

Recent studies show that medical marijuana use can decrease the abuse and need of prescription opioids. Medical marijuana, when used in conjunction with opioids, has augmenting effects on chronic pain management, thus necessitating lower doses of prescription opioids (Abrams et. al. 2011). Individuals using medical marijuana while undergoing opioid detoxification treatment are more likely to complete the treatment program (Bisaga et. al. 2015). In light of these recent findings on medical marijuana use and legalization as it relates to opioids suggests that a substitution, not a gateway, effect is present. To understand the relationship

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[10] By contrast, Wen, Hockenberry, and Cummings (2014) find that medical marijuana laws increased binge drinking for individuals over the age of 21.

between hard, illicit drugs, specifically heroin, and medical marijuana, the relationship between prescription opioid use and the transition into heroin must be spelled out.

Prescription opioid use and abuse was on the rise for most of the 1990s and 2000s (Volkow 2014). Medical use of prescription opioids is positively correlated with prescription opioid abuse (Gilson et. al. 2014), and prescription opioid abuse has also been on the rise for most of the 2000s.[11] Many heroin users initiated their abuse with prescription opioids.[12] Prescription opioids used for abuse are often obtained through various diversion channels, including pilfering an in-house or extended family member's prescription, friends or acquaintances, or their own prescription (Lankenau et. al. 2012, p. 39-40). Cicero et. al. (2014) document a significant change in the pattern of heroin abuse onset—"75% of [individuals who self-reported a primary drug of heroin] who began their opioid abuse in the 2000s reported that their first regular opioid was a prescription drug" compared to "those who began their opioid abuse in the 1960s, [where] more than 80% indicated that they initiated their abuse with heroin" (p. 823).

Prescription opioid users switch into heroin when obtaining prescription opioids for the purposes of abuse becomes more difficult and costly. Cicero et al. (2014) find that 94% of the heroin users in their sample "indicated that they used heroin because prescription opioids were far more expensive and harder to obtain" and that 48.5% of the respondents "who indicated a primary drug of heroin actually preferred prescription opioids when presented with a hypothetical world where there were no limiting factors to what drug they could have" (p. 824). Opioid users also switch into heroin when their preferred opioid becomes too difficult to abuse, such as when abuse-deterrent modifications are made to prescription opioids, like was the case with OxyContin (Cicero et. al 2012).

Given that heroin abuse frequently starts with prescription opioid abuse, many opioid abusers initiated access through diversion of a legitimate prescription, and there is mounting evidence that medical marijuana is a substitute for prescription opioids, legalization of medical

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[11] Gilson et. al. (2014) find that between 1997-2002, drug abuse-related emergency room visits where prescription opioids like fentanyl, hydromorphone, morphine, oxycodone, and hydrocodone were mentioned, increased between by 100 and upwards 600 percent, depending on the specific substance.

[12] Peavy et. al. (2012) report that approximately 39% of their sample were abusing prescription drugs prior to using heroin (p. 261). Lankenau et. al. (2012) find that in their sample of 50 persons, over 80 percent of the individuals started opioid misuse prior to heroin (p. 39).

marijuana could lead to reductions in heroin use. In the next section, we present the data that we use to test whether this substitution effect or the gateway effect best characterizes the relationship between medical marijuana and heroin.

3.   Data

        Given these competing hypotheses on the effect of medical marijuana legalization on heroin use, we empirically test this relationship using the NSDUH Restricted-Use Data Analysis System (R-DAS) state-level estimates on the number of individuals that use heroin.[13] Due to significant privacy and confidentiality restrictions, the only publicly available state-level measure of heroin use is the estimated number of individuals that have ever used heroin.[14] In addition, SAMHSA has also restricted the years of data available for confidentiality purposes. As such, these drug use aggregates are available for 2002-2013 in increments of two-year averages. The state legalization dates and facts (outlined in Table 1) came from the various state governments' websites and marijuanaprocon.org. During the 2002-2013 time period, eleven states changed the legal standing of medical marijuana (Arizona, Connecticut, Delaware, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New Mexico, Rhode Island, and Vermont).[15] Eight states legalized medical marijuana prior to 2002 (Alaska, California, Colorado, Hawaii, Maine, Nevada, Oregon, and Washington). Figure 1 gives a comparison of each of the group categories, always legal between 2002-2013, never legal between 2002-2013, and changed legal standing between 2002-2013. The figure shows the estimated number of individuals that have ever used heroin per 1,000 people.

(insert Figure 1 about here)

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[13] Zacny et al. (2003) suggest that since the NHSDA data limit their sample to individuals living in households, shelters, and rooming houses, the data "may provide an underestimate of the prevalence of substance abuse/dependence" because it does not capture individuals without homes such as homeless people that do not take up residence in shelters (p. 219).

[14] In the restricted-access data, this variable is called *herever*.

[15] The District of Columbia also changed the legal standing of medical marijuana during this time, but due to insufficient data and the imprecision of comparing a city to the other fifty states, the District of Columbia was dropped from the sample.

An alternative way of looking at the progression of heroin use over time is to examine which states have the highest and lowest estimated number of individuals that have ever used heroin per 1,000. Oregon, Rhode Island, Maryland, New Hampshire, and Washington have the highest average rates of individuals that have ever used heroin between 2002-2013, respectively. Vermont, Alaska, Connecticut, Nevada, and Massachusetts have the fifth through tenth highest average rates of individuals that have ever used heroin between 2002-2013, respectively. In four of the states in this top 10 category (Alaska, Nevada, Oregon and Washington), medical marijuana has always been legal during the 2002-2013 time period. In five of the states in this top 10 category (Connecticut, Massachusetts, New Hampshire, Rhode Island, and Vermont), medical marijuana changed its legal status during the 2002-2013 time period. Only one state, Maryland, in this top 10 group never had legal medical marijuana. However, this is only a limited view of the effect of medical marijuana on heroin use, as this preliminary analysis does not include additional controls.

South Dakota, North Dakota, Nebraska, Kansas, and Alabama have the lowest average rates of individuals that have ever used heroin per 1,000 during the 2002-2013 time period, respectively. Mississippi, Iowa, Georgia, Wisconsin, and South Carolina have the sixth through tenth lowest average rates of individuals that have ever used heroin during the 2002-2013 time period, respectively. In all of these states, medical marijuana did not have legal standing. Figure 2 illustrates these different state group rates over the relevant time period.

(insert Figure 2 about here)

While we aim to examine the effect of the legalization of medical marijuana on heroin rates, there could be reason to believe that the decision to legalize medical marijuana is driven by opioid use or vice versa. In order to identify the impact of the legalization of medical marijuana on heroin use free of potential endogeneity, one must find an instrument that predicts changes in the likelihood that medical marijuana would be legalized in a particular state/region, but that is unrelated to changes in heroin use. In what follows, we propose state-level politico-economic variables as plausible instruments for the legalization of medical marijuana. Namely, we use

long-run state deficits and Republican representation in the State Senate, State House of Representatives/Delegates and Governor seats as instruments for the legalization of medical marijuana. Factors such as persistent debt, conservative and liberal beliefs, and political momentum are empirically correlated with social changes, such as beliefs about the legalization of drugs, gay rights, and other related issues.

The use of politico-economic variables as instruments for the legalization of medical marijuana requires that heroin use and these variables not share channels that jointly vary the number of heroin users as well as state-level debt and conservative political presence. While it does not appear that any direct channels between the instruments and heroin use would exist, it is possible that the composition of the government could impact expenditures on health care, which could impact heroin rates. To address this issue, we include measures of state-sponsored drug facilities and medical expenditures, as well as drug overdose rates from the previous year. Additionally, we include measures of income, education levels, age, and demographic controls. Table 2 provides summary statistics for the variables used in this analysis.

(insert Table 2 about here)

The state surplus/deficit numbers were calculated from the U.S Census Bureau's *Annual Survey of State Government Finances* by subtracting the total expenditures from total revenue. The state government healthcare expenditures were also taken from these reports. The state legislature partisan data was obtained from the *Composition of State Legislatures by Political Party Affiliation* database put out by the Council of State Governments for the years 2002-2009 and the *State and Legislative Partisan Composition* annual reports written by the National Conference of State Legislatures for the years 2010-2013. The political affiliation of state governors came from *The Governors, Political Affiliations, and Terms of Office* annual reports from the Office of Public Affairs of the National Governors Association.

The availability of medical marijuana within a state is an important factor in analyzing its potential as a gateway drug. However, there are concerns about the heterogeneity of medical marijuana laws, particularly regarding the retail availability of medical marijuana. Additionally,

many states with similar laws have different regulatory burdens on dispensary owners, thus leading to substantial differences in availability across states that have very similar laws. For example, Oregon and Colorado had non-registered dispensaries open for several years before the law recognized legal dispensaries. Other states like Vermont allowed legal dispensaries, but it took several years for one to open due to many regulatory and permit issues. In order to limit arbitrary judgment calls between states with drastically different de jure and de facto restrictions on dispensaries, we include a control for the presence of state-registered medical marijuana dispensaries. The dates of the first state-registered medical marijuana dispensaries were acquired from Pacula et al. (2015).[16] Our control, *Dispensaries*, utilizes these dates and takes on the value of 1 if at least one state-registered dispensary was open for business within a state throughout the year.

The numbers of opioid (including heroin, methadone, and opium) overdose deaths in the previous year were obtained from the CDC Wonder's *Multiple Causes of Death, 1999-2013* database. The total number of operational substance abuse facilities was obtained from annual reports from the National Survey of Substance Abuse Treatment Services (N-SSATS). The state-level prescription drug monitoring program data was acquired from the Prescription Drug Monitoring Program Training and Technical Assistance Center. The annual state-level unemployment rates were obtained from the U.S. Bureau of Labor Statistics. The remaining controls, including educational attainment, median income, the percentage of the state population living below the poverty line, race demographics, age demographics, and gender demographics were all collected from various reports and databases put out by the U.S. Census Bureau. A detailed explanation of each variable and its source can be found in Appendix I.

The first column of Table 2 provides annual summary statistics from 2002-2013 for all states. The marijuana rates are approximately 7 times larger than heroin usage rates. Average surplus/deficits are not statistically different from zero. Additionally, Republican presence in legislature and governor positions is approximately equal to non-Republican presence.

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[16] Pacula et. al. (2015)'s open dispensary dates are "as of January 1, 2012." This does not include states that legalized medical marijuana within the 2012-2013. We verified that all of the states that legalized in this time period did not open state-registered medical marijuana dispensaries prior to December 31, 2013. Connecticut and Massachusetts opened state-registered medical marijuana dispensaries after 2013, and New Hampshire has not yet operationalized state-registered medical marijuana dispensaries.

The second, third and fourth columns examine the summary statistics for locations that have always had legal medical marijuana, never legalized medical marijuana, and changed legal standing, respectively, in our sample period. The fifth column reports t-statistics that compare locations that have always permitted the use of medical marijuana laws to states that have changed during our sample period (first entry) as well as locations that never legalize to changing locations (second entry). Locations that have always and never permitted the legal use of medical marijuana are statistically different from locations that change their laws during our sample. Notably, states that never change their laws have a statistically larger Republican presence in state government leadership positions as well as lower heroin and marijuana usage rates. States that have always permitted the legal use of medical marijuana spend more on medical expenditures, are more likely to have a prescription drug programs, and have a smaller White population.

4.   Model & Results

The first stage relationship between state deficit/surplus, political composition and medical marijuana laws can be estimated as follows:

$$Med.\,Marij\,Change_{st} = \beta_1 5\,Year\,Deficit_{st} + \beta_2 Repub.\,Legis_{st} + \beta_3 Repub.\,Gov_{st} + X_{st} + \lambda_s + \varepsilon_{st}$$
$$(1)$$

where *s* indexes the state and *t* captures the year. The *Med. Marij. Change* variable is dichotomous and measures whether a state experienced a change in the legalization of medical marijuana during that year. *5 Year Deficit* measures a state's deficit/surplus over the previous five years while *Repub. Legis.* measure the percentage of republicans filling seats in the State House and Senate. *Repub. Gov.* is a dichotomous variable that indicates whether the state's governor is affiliated with the Republican Party. In addition to these variables, we include a range of other covariates, including the unemployment rate; median income; poverty rate; percent of individuals aged 18-24, 25-44 and 45-64; percent White and Black; number of drug facilities in the state; the previous year's overdose rates per million individuals; the presence of a prescription drug monitoring program, whether or not a state-registered medical marijuana dispensary was open, and medical expenditures per capita. State-fixed effects are also included in the analysis. Finally, because our identification is based on variation in the passage of medical

marijuana laws at the state-level, we allow for arbitrary correlation in the error by clustering at the state-level.

(Insert Table 3 about here)

In order to account for potential lags or institutional effects of long-run deficit and conservative control over the legislative process, we estimate equation (1) with the instruments lagged by 1, 2, 3, 4 and 5 years. The first five columns of Table 3 present the fully specified first-stage estimates of equation (1) with lagged instruments. Republican presence in state government positions are positively correlated with the likelihood that a state changes their laws to make medical marijuana use legal for up to a 3-year lag. After 3 years, the correlation switches to negative.

The last five columns of Table 3 show the reduced-form relationship between the politico-economic instruments and heroin rates. We observe a significant negative relationship between increases in the percentage of republicans in the state legislative positions and heroin rates, especially when it is lagged two to four years. Additionally, Republican governors also appear to share a negative relationship with heroin rates.

We model the relationship between heroin rates and changes in medical marijuana laws as

$$Ln(Heroin\ Rate)_{st} = \gamma Med.Marij.Law_{st-x} + X_{st} + \lambda_s + \varepsilon_{st} \qquad (2)$$

where *Heroin Rate* is the reported usage rate of heroin in state *s* in year *t* and, depending on the specification, *Med. Marij. Law* is a lagged variable that denotes whether medical marijuana legislation was passed *x* years ago. We lag the medical marijuana variable in order to account for potential institutional effects.

(Insert Table 4 about here)

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Ordinary Least Squares estimates are presented in the first five columns of Table 4 with additional controls and state fixed-effects. These estimates are identified using variation in the timing of the passing of legislation that made medical marijuana legal. As previously discussed, there are reasons to believe that the legalization of marijuana could become a channel for increasing or decreasing the use of opioids. Our longer-term results reflect this, as we find that changes in medical marijuana laws are positively and statistically significantly related to heroin usage rates. Moreover, states that adopt laws that legalize medical marijuana are likely to experience a selection effect, whereby the citizens and their represented officials are systematically different from non-adopting states.

To overcome the likely endogeneity associated with the selection of states that legalize medical marijuana laws, we explore politico-economic variables that likely have an impact. First, medical marijuana yields significant tax revenues for many states that legalize (Joint Fiscal Office, 2012; Hesson 2014). As such, states that have experienced persistent fiscal deficits might find the legalization of medical marijuana an attractive option if it leads to increased tax revenue. Additionally, certain political affiliations, namely individuals affiliated with conservative parties, are more likely to oppose the legalization of medical marijuana.[17] As previously noted, though, it is unlikely that long-run state surpluses/deficits or the composition of the legislative body will directly impact heroin use.[18]

Columns (vi) – (x) in Table 4 report the state-level instrumental variable estimates of the legalization of medical marijuana on heroin usage. Again, we lag the passage of the medical marijuana law passage for up to five years in order to determine if an institutional or market establishment process impacts the relationship.[19] Our IV results fail to find a significant

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[17] When polled, Republicans are less in favor of marijuana legalization (than independents and democrats. See the "Views of Legalizing Marijuana, 1969-2015" from Gallup, General Social Survey, and Pew Research Center (2015). There are several examples of Republican officials opposing medical marijuana legalization. In 2003, 208 Republican Representatives (out of 228) voted against an amendment (CR H7354) to H.R. 2799 to limit the federal government from interfering with states authorizing the use of medical marijuana (Roll Call 420). Rhode Island Republican Governor vetoed medical marijuana bill in 2005 that was ultimately passed in 2007 by a veto override (Wang 2009). In 2007, the Republican governor of Connecticut vetoed a bill that would legalize marijuana (Malone 2007).

[18] The F-statistic associated with estimating the relationship between medical marijuana legalization and the politico-economic variables that we utilize as instruments is always larger than 10.

[19] While legislation that legalizes medical marijuana can be passed relatively straightforwardly, the process of establishing permits, identification cards and institutionalizing the system could be a lengthy and laborious process. Furthermore, the effect of fewer individuals diverting to heroin as a result of prescription opioid substitution into

relationship between the legalization of medical marijuana and heroin use in the short run or in any of the five years after the change. This could be due to the fact that only 11 out of 50 states make such changes, that medical marijuana and heroin do not share an established relationship, or that the relationship is difficult to establish.

In order to further explore the relationship between law changes and heroin use, and given the timing of the changes in laws over time and across states, we can further exploit our data by comparing locations that pass laws that legalize medical marijuana to those that do not to conduct a difference analysis. To further explore the relationship, we continue to make use of the instruments that we have already identified, but explore a different specification. Equation (3) establishes the relationship between heroin rates and medical marijuana laws as

$$Ln(Heroin\ Rate)_{st} = \alpha_1 Med.Marij.Legal_s + \alpha_2 Med.Marij.Legal_s\ x\ Med.Marij.Law_{st-x} +$$
$$X_{st} + \lambda_s + \varepsilon_{st} \qquad (3)$$

where $Med.Marij.Legal_s$ is a dichotomous variable that takes on the value 1 if a state ever legalizes medical marijuana and zero otherwise. By including this variable we attempt to separately identify the selection effect of adopting states. Additionally, we interact this variable with *Med. Marij. Law* in order to identify the impact of the timing of the change in the law on heroin use. Thus, specification (3) utilizes a difference approach to examine the impact of the passage of medical marijuana legislation on heroin use rates while also controlling for compositional differences in adopting and non-adopting states. We continue to use the politico-economic instrumental variables discussed above to determine whether a state passes legislation or not. We run both the OLS and IV regressions and report them in Table 5.

(insert table 5 about here)

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medical marijuana as a treatment option would take time to show up, as the transition from prescription opioid use to opioid abuse to heroin abuse is not instantaneous.

Columns (i)-(v) of Table 5 display the OLS results of equation (3), with no statistically significant results. In columns (vi) – (x) we estimate equation (3) using the instruments discussed above. We confirm the results of Table 3, but with an additional wrinkle. Approximately three years after the legal change and only in locations that experienced this change, we observe an approximately 300 percent reduction in heroin usage, but this is only significant at the 10 percent level. Thus, after attempting to control for selection associated with states that legalize medical marijuana, we do not find a significant relationship between marijuana and heroin use.

5.   Discussion & Conclusion

In order to further understand the relationship between medical marijuana legalization and heroin use, we developed three different specifications to examine this relationship. Building on the previous literature, we identified two possible relationships: the gateway effect and the substitution effect. The gateway effect would be categorized by an increase in heroin use as a result of previous medical marijuana legalization. The substitution relationship would manifest through more individuals choosing medical marijuana over prescription opioids, thus decreasing the number of diversions to heroin. Our results, however, suggest that neither of these relationships are persistent or statistically significant. These results are consistent with Wen, Hockenberry, and Cummings (2014), who find that medical marijuana legalization does not lead to changes in hard-drug use. We do not find compelling negative trends in heroin use as a result of medical marijuana legalization like those in Bachhuber et al. (2014) on overdose.[20]

In the third model, which most accurately models the potential relationship between legalization of medical marijuana and heroin use by isolating the effect of the states that have chosen to legalize interacted with those states that changed their law in the previous year(s) (depending on the lag), we only find once instance of statistical significance in IV estimation with the 3 year lag. From our results, we can conclude that while legalization of medical marijuana does not clearly lead to decreases in heroin use, it is also not a gateway drug for heroin. Thus, many of the concerns expressed in the mid-1990s at the beginning of state-level medical marijuana legalization did not transpire.

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[20] We also estimated the effect of medical marijuana legalization on state opioid overdose rates. We estimated OLS specification of equation (2), and we only changed the dependent variable to the natural log of the overdose rate in the present period and we dropped the lagged overdose dose rate control from the right hand side. The coefficients on *Med. Marij. Law* were negative, but statistically insignificant.

The lack of a clear relationship could be due to many factors. The data on drug use is very restricted, especially at the individual level. Relying on state-level aggregates limits the insight into drug-switching behaviors, as well as other environmental and genetic factors. Furthermore, heroin users make up such a small percentage of a state's population that small changes in the number of heroin users result in massive fluctuation of the per capita rates, which explains the large standard deviations across all states. Referring back to Figure 2, even the top 5 states with the highest number of heroin users never had more than 25 users per 1,000 individuals on average while the lowest 5 states never had more than 10 users per 1,000 individuals on average. Due to these aggregation limitations, we are very cautious not to propose policy implications and suggested changes based on the specific point estimates within the model. However, the general trend of negative coefficients under the IV estimations, as well as positive, but very small coefficients under the OLS estimations, factoring in the lack of statistical significance suggests that at a minimum, medical marijuana legalization did not have a substantial effect on heroin use.

Individual-level data, if it were publicly available, would allow for us to control for more factors and variation at the individual level such that we can see how different people respond to legal changes both within and across states. However, even if individual level data were available, modeling drug use behavior would still be difficult due to the absence of the relevant counterfactual. Specifically, it is impossible to know if an individual would have otherwise become a heroin abuser had they chosen prescription opioids over medical marijuana.

Recent research has found many reasons to believe that medical marijuana legalization helped to decrease other problems such as traffic fatalities, binge drinking among young people, opioid analgesic overdoses, and violent crime rates. Other studies have found that medical marijuana legalization, while it is associated with higher marijuana use, did not have an effect on hard drug use. Our study finds that while the positive outcomes associated with medical marijuana legalization and opioid abuse/overdose cannot be extended to heroin use, we found results consistent with the recent research that medical marijuana legalization did not lead to increases in heroin use.

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Table 1. States with Legal Medical Marijuana

State	Vote: Legislative (L) or Popular (P)			Legislation Approved	Signed into Law (if different than approval)	Effective Date
Alaska	Ballot Measure 8	(58%)	(P)	November 3, 1998		March 4, 1999
Arizona	Ballot Proposition 203	(50.13%)	(P)	November 2, 2010		April 14, 2011
California	Ballot Proposition 215	(56%)	(P)	November 5, 1996		November 6, 1996
Colorado	Ballot Amendment 20	(54%)	(P)	November 7, 2000		June 1, 2001
Connecticut	HB 5389		(L)	May 4, 2012	May 31, 2012	May 4, 2012 & October 1, 2012
Delaware	Senate Bill 17		(L)	May 13, 2011		July 1, 2011
District of Columbia	Amendment Bill B18-622		(L)	May 4, 2010	May 21, 2010	July 27, 2010
Hawaii	Senate Bill 862		(L)	June 14, 2000		December 28, 2000
Illinois	House Bill 1		(L)	May 17, 2013	August 1, 2013	January 1, 2014
Maine	Ballot Question 2	(61%)	(P)	November 2, 1999		December 22, 1999
Maryland	House Bill 881		(L)	April 8, 2014	April 14, 2014	June 1, 2014
Massachusetts	Ballot Question 3	(63%)	(P)	November 6, 2012		January 1, 2013
Michigan	Proposal 1	(63%)	(P)	November 4, 2008		December 4, 2008
Minnesota	S.F. 2470		(L)	May 29, 2014		May 30, 2014
Montana	Initiative 148	(62%)	(P)	November 2, 2004		November 2, 2004
Nevada	Ballot Question 9	(65%)	(P)	November 7, 2000		October 1, 2001
New Hampshire	House Bill 573		(L)	May 23, 2013	July 23, 2013	July 23, 2013
New Jersey	Senate Bill 119		(L)	January 11, 2010	January 18, 2010	October 1, 2010
New Mexico	Senate Bill 523		(L)	March 13, 2007		July 1, 2007
New York	Assembly Bill 6357		(L)	June 20, 2014	July 5, 2014	July 5, 2014
Oregon	Ballot Measure	(55%)	(P)	November 3, 1998		December 3, 1998
Rhode Island	Senate Bill 0710		(L)	January 3, 2006	January 3, 2006 (veto override)	January 3, 2006
Vermont	Senate Bill 76 & House Bill 645		(L)	May 26, 2004	passed unsigned	July 1, 2004
Washington	Ballot Initiative I-692	(59%)	(P)	November 3, 1998		November 3, 1998

Figure 1: Estimated Number of Heroin (Ever) Users per 1,000 Individuals by State Legal Standing
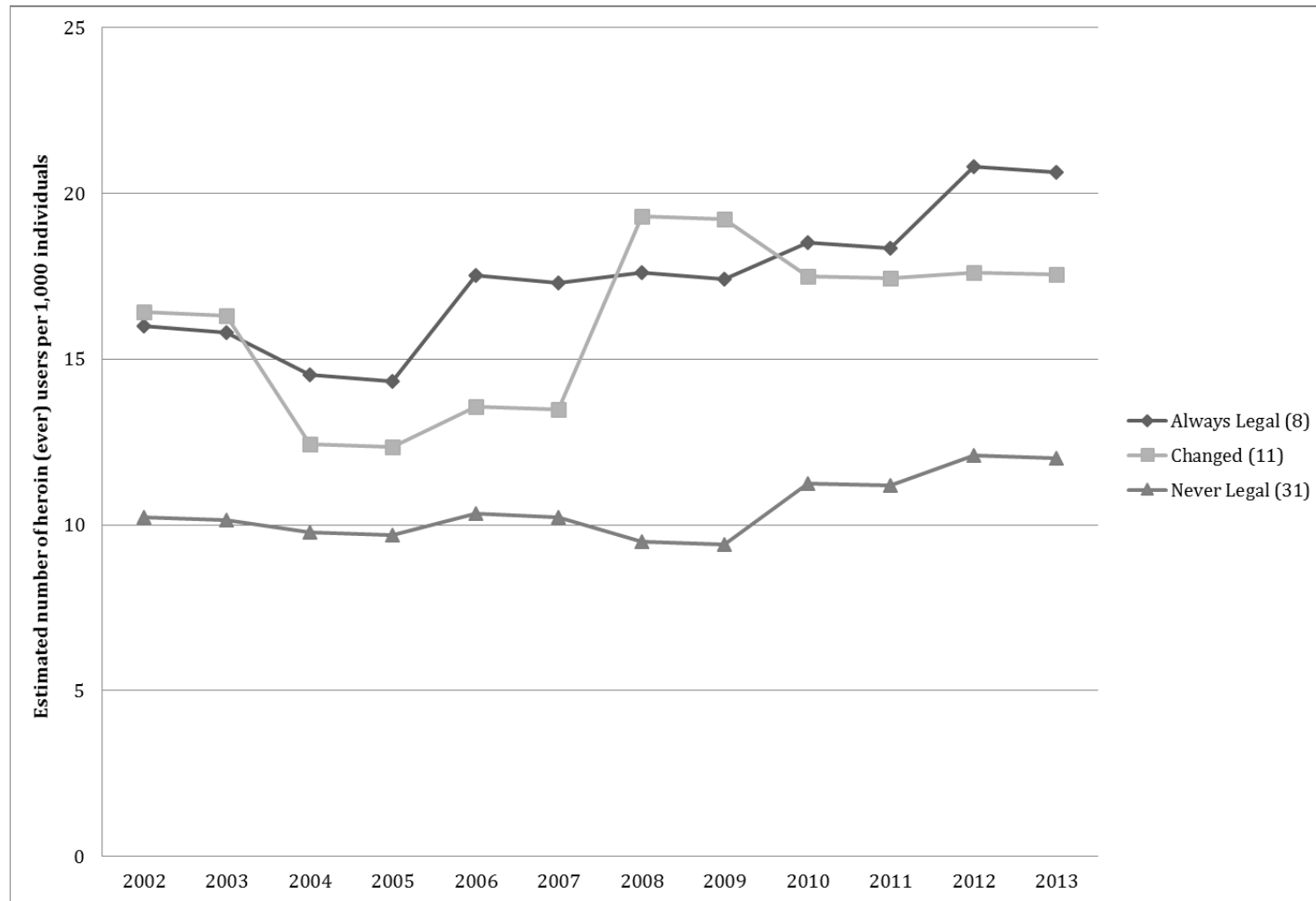
Figure 2: Estimated Number of Heroin (Ever) Users per 1,000 Individuals by State Ranking
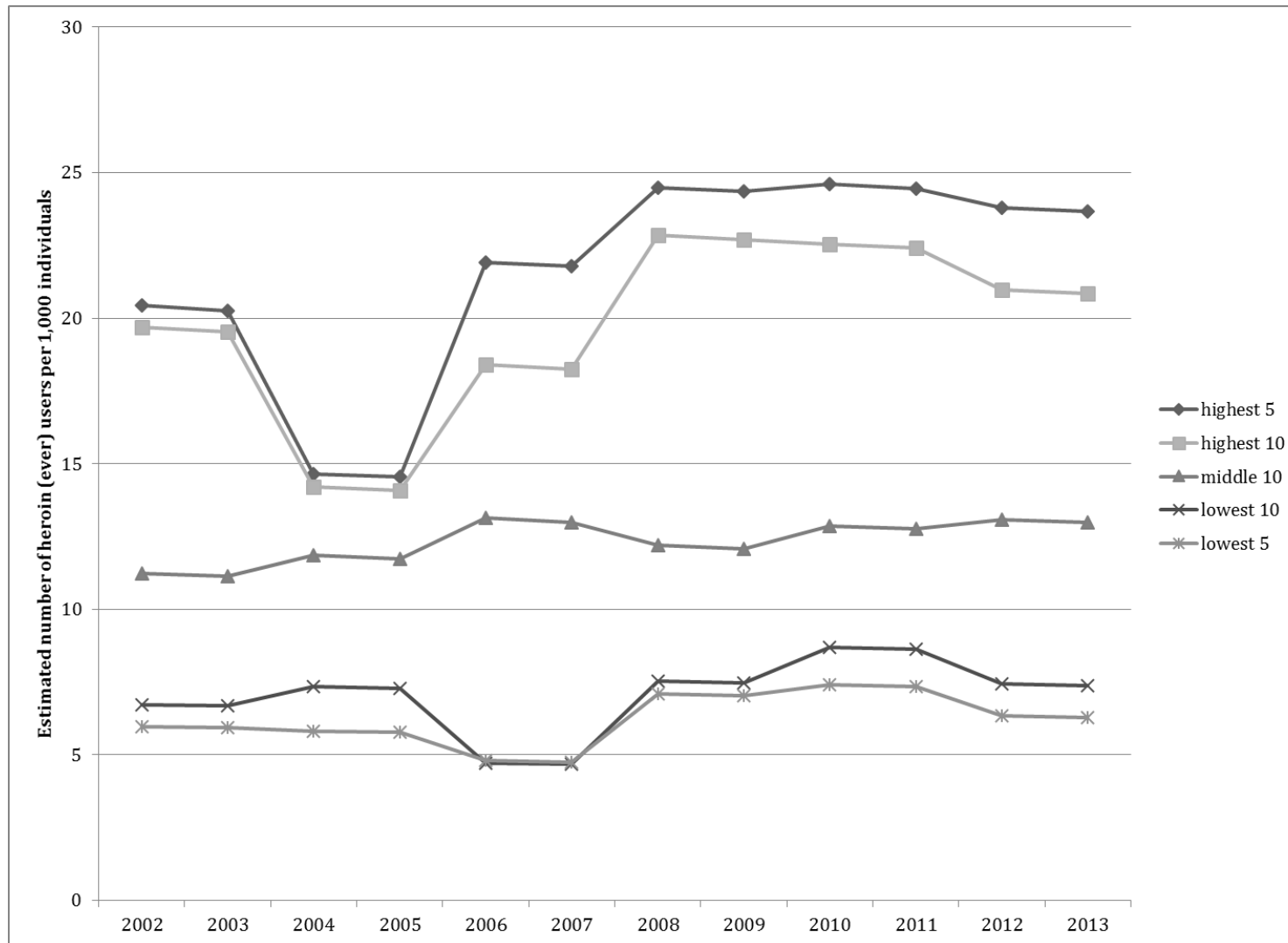
Table 2: Summary Statistics

	All States N = 600	Always Legal N = 96	Never Legal N = 372	Changing States N = 132	t-test
Heroin (Ever) Usage Rate	0.013 (0.006)	0.017 (0.006)	0.010 (0.005)	0.016 (0.005)	-1.539 / 13.995***
Marijuana (Past Year) Usage Rate	0.092 (0.024)	0.117 (0.022)	0.079 (0.012)	0.112 (0.024)	-4.952*** / 26.225***
Surplus/Deficit (in billions)	0.532 (10.862)	0.788 (20.824)	0.720 (8.756)	-0.137 (4.221)	0.262 / -0.586
Percentage of Republican in State Senate	0.493 (0.182)	0.425 (0.126)	0.541 (0.177)	0.405 (0.176)	0.114 / -7.842***
Percentage of Republican in State House	0.490 (0.159)	0.425 (0.126)	0.535 (0.145)	0.414 (0.172)	0.490 / -8.661***
Republican Governor	0.525 (0.500)	0.490 (0.503)	0.575 (0.495)	0.062 (0.028)	-1.726* / -1.915*
Overdoses per capita (per thousand)	0.051 (0.003)	0.064 (0.033)	0.046 (0.036)	0.056 (0.026)	-4.824*** / 6.127***
Number of Facilities per capita (per thousand)	0.060 (0.036)	0.089 (0.040)	0.053 (0.021)	0.059 (0.012)	-6.069*** / 10.768***
Median Income	54,350.36 (8342.018)	59,427.450 (6040.473)	51,637.00 (7295.925)	58,304.69 (9243.008)	4.251*** / 7.944***
Dispensaries	0.095 (0.293)	0.375 (0.487)	0.000 (0.000)	0.159 (0.367)	-6.803*** / 14.990***
Population (millions)	6.034 (6.647)	7.192 (1.130)	6.533 (5.682)	3.786 (3.299)	-1.299 / -1.229
Percent in Poverty	0.128 (0.0329)	0.118 (0.021)	0.130 (0.031)	0.119 (0.037)	-3.773*** / -3.316***
Percent Graduated High School	0.867 (0.0362)	0.879 (0.034)	0.861 (0.037)	0.876 (0.030)	-1.780* / 5.397***
Percent with Bachelors	0.272 (0.048)	0.286 (0.040)	0.256 (0.044)	0.305 (0.045)	2.808*** / 8.573***
Unemployed	0.062 (0.021)	0.068 (0.023)	0.060 (0.020)	0.062 (0.021)	-4.680*** / 4.420***
Percent White	0.813 (0.123)	0.759 (0.206)	0.813 (0.102)	0.851 (0.069)	2.397** / -1.407
Percent Black	0.105 (0.095)	0.039 (0.023)	0.133 (0.104)	0.076 (0.066)	5.276*** / -9.686***
Percent Male	0.493 (0.007)	0.501 (0.009)	0.492 (0.006)	0.490 (0.006)	-7.941*** / 8.261***

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Percent Age 18-24	0.101 (0.008)	0.098 (0.006)	0.102 (0.008)	0.099 (0.007)	-3.148*** / -3.608***
Percent Age 25-44	0.268 (0.016)	0.279 (0.016)	0.267 (0.014)	0.262 (0.017)	1.632 / 0.811
Percent Age 45-64	0.259 (0.020)	0.262 (0.018)	0.254 (0.018)	0.268 (0.021)	-3.22*** / 7.853***
Prescription Drug Monitoring Program	0.582 (0.494)	0.625 (0.487)	0.594 (0.492)	0.515 (0.502)	-3.836*** / 1.166
Health Care Expenditures (millions)	1,123.736 (1683.722)	1,737.887 (2997.383)	1,114.092 (1401.601)	704.261 (655.650)	-1.746* / 1.138

Standard deviations are reported in parenthesis
*, **, and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Table 3: The Relationship Between Heroin, Medical Marijuana and Politico-Economic Factors

	First Stage					Reduced Form				
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Dependent variable: Medical Marijuana Law Change					Dependent Variable: Ln(Heroin Rate)				
	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag
5 Year Surplus/Deficit (billions)	272.590 (413.998)	66.950 (425.211)	121.750 (400.469)	420.726 (354.766)	716.625* (391.790)	-1149.074* (620.739)	-1175.681 (763.705)	-638.376 (802.593)	-899.068 (799.661)	-657.021 (817.268)
% Repub. Legislature	0.119 (0.326)	0.314 (0.450)	0.088 (0.412)	0.049 (0.341)	-0.303 (0.311)	-0.246 (0.409)	-0.583** (0.286)	-1.051*** (0.405)	-0.775 (0.532)	-0.272 (0.750)
Republican Governor	0.028 (0.039)	0.019 (0.035)	-0.000 (0.035)	-0.033 (0.034)	-0.046 (0.030)	-0.014 (0.057)	-0.070 (0.046)	-0.102** (0.046)	0.065 (0.075)	0.058 (0.060)
Median Income (thousands)	-0.006 (0.005)	-0.006 (0.004)	-0.004 (0.005)	-0.001 (0.005)	-0.002 (0.005)	0.013* (0.007)	0.015** (0.007)	0.016** (0.008)	0.008 (0.009)	0.011 (0.009)
Dispensaries	0.249** (0.103)	0.226** (0.104)	0.212** (0.099)	0.161* (0.090)	0.095 (0.077)	0.033 (0.058)	0.039 (0.057)	-0.015 (0.057)	-0.056 (0.067)	-0.076 (0.068)
Number of Facilities	972.380 (1979.539)	1026.505 (2356.284)	394.733 (2316.895)	-369.286 (2313.566)	-1175.149 (2003.523)	-845.900 (3177.159)	-1053.012 (3446.724)	-67.765 (3116.262)	394.047 (3129.006)	359.313 (3477.961)
Overdose Rate	51.538 (745.608)	26.310 (723.235)	-34.916 (754.714)	-205.329 (715.759)	-193.641 (605.895)	1301.991* (787.489)	1037.363 (851.490)	892.548 (809.807)	547.919 (985.411)	897.973 (1135.726)
Health Expenditures (millions)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000** (0.000)	-0.000** (0.000)	-0.000** (0.000)
Prescription Drug Monitoring Program	0.009 (0.031)	0.012 (0.030)	0.002 (0.032)	0.008 (0.037)	0.013 (0.045)	0.038 (0.061)	0.044 (0.063)	0.032 (0.067)	0.026 (0.085)	0.021 (0.079)
State FE	X	X	X	X	X	X	X	X	X	X
Controls	X	X	X	X	X	X	X	X	X	X
R^2	0.864	0.878	0.881	0.893	0.907	0.692	0.712	0.724	0.734	0.742
Obs.	549	499	449	399	349	549	499	449	399	349

*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.
Controls include education rates, percent male, percent of the population that is Black, percent of the population that is White, percent aged 15-24, 25-44, and 45-64 as well as the percent of the population that is living below the poverty line. Standard errors are clustered at the state level.

Table 4: Measuring the Impact of Medical Marijuana Legalization on Heroin Usage

	Ordinary Least Squares					Instrumental Variables				
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag
Medical Marijuana Law Change	0.036 (0.074)	0.033 (0.081)	0.073 (0.058)	0.146** (0.069)	0.113** (0.055)	-0.639 (1.441)	-2.580 (2.243)	-10.407 (19.805)	-3.536 (4.507)	-0.791 (1.050)
Median Income (thousands)	0.010 (0.008)	0.009 (0.008)	0.010 (0.008)	0.009 (0.007)	0.009 (0.008)	0.007 (0.010)	0.007 (0.012)	-0.047 (0.119)	-0.001 (0.014)	0.011 (0.012)
Dispensaries	0.013 (0.063)	0.012 (0.074)	-0.006 (0.070)	-0.034 (0.071)	-0.018 (0.064)	0.264 (0.512)	0.985 (0.801)	2.900 (5.642)	0.674 (0.811)	0.074 (0.223)
Number of Facilities	-822.191 (3205.690)	-823.893 (3242.857)	-901.624 (3237.338)	-999.128 (3255.114)	-801.654 (3253.081)	457.882 (4982.393)	6793.948 (8257.199)	16540.570 (35460.630)	286.123 (9282.534)	-1552.846 (3946.467)
Overdose Rate	1395.973* (787.643)	1398.056* (798.822)	1366.282* (812.649)	1297.250 (797.369)	1311.852* (768.581)	1302.302 (804.027)	383.640 (1556.397)	-1766.114 (9982.164)	-1040.807 (3005.671)	1211.260 (1253.721)
Health Expenditures (millions)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)	-0.000 (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Prescription Drug Monitoring Program	0.025 (0.063)	0.025 (0.063)	0.027 (0.063)	0.027 (0.062)	0.024 (0.061)	0.048 (0.064)	0.062 (0.113)	-0.100 (0.423)	0.005 (0.191)	0.051 (0.103)
State FE	X	X	X	X	X	X	X	X	X	X
Controls	X	X	X	X	X	X	X	X	X	X
R^2	0.688	0.688	0.688	0.691	0.690	-	-	-	-	-
Obs.	549	499	449	399	349	549	499	449	399	349

*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Controls include education rates, percent male, percent of the population that is Black, percent of the population that is White, percent aged 15-24, 25-44, and 45-64 as well as the percent of the population that is living below the poverty line. Standard errors are clustered at the state level.

Table 5: Measuring the Impact of Medical Marijuana Legalization on Heroin Usage with a Difference Model

	Ordinary Least Squares					Instrumental Variables				
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag
Med. Marij. Ever Legal	1.182 (1.158)	1.198 (1.158)	1.194 (1.152)	1.167 (1.153)	1.133 (1.161)	-6.961 (10.803)	-11.102 (14.612)	-16.781 (15.435)	-6.553 (15.625)	-1.943 (13.693)
Med. Marij. Ever Legal x Med. Marij. Law	0.012 (0.084)	-0.035 (0.088)	-0.123 (0.085)	0.029 (0.071)	0.110 (0.074)	-1.624 (2.720)	-2.642 (2.227)	-3.002* (1.720)	-1.701 (1.938)	-0.146 (1.952)
Median Income (thousands)	0.009 (0.008)	0.009 (0.008)	0.009 (0.008)	0.009 (0.008)	0.009 (0.008)	0.008 (0.014)	0.023** (0.009)	0.006 (0.012)	0.006 (0.009)	0.010 (0.014)
Dispensaries	0.033 (0.061)	0.034 (0.060)	0.034 (0.061)	0.033 (0.060)	0.028 (0.062)	-0.013 (0.127)	0.216 (0.244)	0.110 (0.201)	-0.096 (0.120)	-0.085 (0.093)
Number of Facilities	-667.947 (3186.203)	-664.716 (3193.234)	-521.630 (3229.271)	-709.378 (3211.046)	-766.495 (3181.446)	-1737.801 (4332.916)	46.427 (4332.558)	1936.855 (5728.222)	2275.995 (5333.079)	318.701 (4176.948)
Overdose Rate	1488.533* (765.190)	1485.774* (775.085)	1433.024* (751.581)	1517.931** (764.719)	1499.869* (785.968)	1682.643 (1436.916)	1583.407 (1999.990)	969.937 (1466.713)	-794.043 (1556.170)	847.595 (1274.288)
Health Expenditures (millions)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Prescription Drug Monitoring Program	0.026 (0.063)	0.027 (0.062)	0.024 (0.062)	0.028 (0.063)	0.027 (0.063)	0.068 (0.095)	0.107 (0.109)	0.033 (0.100)	-0.010 (0.103)	0.030 (0.079)
State FE	X	X	X	X	X	X	X	X	X	X
Controls	X	X	X	X	X	X	X	X	X	X
R^2	0.688	0.688	0.689	0.688	0.688	0.435	0.152	0.175	0.522	0.673
Obs.	549	499	449	399	349	549	499	449	399	349

*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Controls include education rates, percent male, percent of the population that is Black, percent of the population that is White, percent aged 15-24, 25-44, and 45-64 as well as the percent of the population that is living below the poverty line. Standard errors are clustered at the state level.

Appendix I

Variable	Description	Source
heroin (ever) rate	estimated number of people that have ever used heroin per capita	NSDUH 2-Year Restricted-use Data Analysis System, 2002-2013, Substance Abuse and Mental Health Data Archive, variable name: *herever*
marijuana (past year) rate	estimated number of people that have used marijuana in the past year per capita	NSDUH 2-Year Restricted-use Data Analysis System, 2002-2013, Substance Abuse and Mental Health Data Archive, variable name: *mrjyr*
med.marij.legal	=1 if medical marijuana is legal and in effect	MarijuanaProCon.org & state government webpages
surplus/deficit	total amount of surplus (+)/deficit (-) for state government (in billions)	U.S. Census Bureau, Annual Survey of State Government Finances, 1997-2013
percent Republican Senate	percentage of state Senate seats held by Republicans	The Council of State Governments, "Composition of State Legislatures by Political Party Affiliation," 2002-2009 & National Conference of State Legislatures, "State and Legislative Partisan Composition" (Annual), 2010-2013
percent Republican House	percentage of state House seats held by Republicans	The Council of State Governments, "Composition of State Legislatures by Political Party Affiliation," 2002-2009 & National Conference of State Legislatures, "State and Legislative Partisan Composition" (Annual), 2010-2013
Republican Governor	=1 if governor is a Republican	National Governors Association, Office of Public Affairs, "The Governors, Political Affiliations, and Terms of Office" (Annual), 2002-2013
dispensaries	= 1 if at least one state-registered dispensary was open for business	Pacula et al. (2015)
overdoses	number of heroin, opium, methadone, and/or other opioid overdoses in previous year per capita	CDC Wonder, Multiple Causes of Death, 1999-2013
facilities	number of substance abuse treatment facilities in operation per capita	National Survey of Substance Abuse Treatment Services (N-SSATS) 2002-2013
median income	median income across the state	U.S. Census Bureau, Current Population Survey, 2002-2013
population	state population (in millions)	U.S. Census Bureau, Population Division, 2002-2013
percent in poverty	percentage of the state population living below 100% of poverty	U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplement, 2002-2013
percent highschool	percentage of total state population 25 and older that has a high school diploma	U.S. Census Bureau, 2002-2013
percent bachelors	percentage of total state population 25 and older that has a bachelor's degree	U.S. Census Bureau, 2002-2013
unemployed	state unemployment rate	U.S. Bureau of Labor Statistics, 2012-2013
percent white	percentage of total state population that is white	U.S. Census Bureau, Population Division, 2002-2013
percent black	percentage of total state population that is black	U.S. Census Bureau, Population Division, 2002-2013
percent male	percentage of total state population that is male	U.S. Census Bureau, Population Division, 2002-2013
percent age 18-24	percentage of total state population that is between 18-24	U.S. Census Bureau, Population Division, 2002-2013
percent age 25-44	percentage of total state population that is between 25-44	U.S. Census Bureau, Population Division, 2002-2013

percent age 45-64	percentage of total state population that is between 45-64	U.S. Census Bureau, Population Division, 2002-2013
pdmp_oper	=1 if a prescription drug monitoring program was in place	Prescription Drug Monitoring Program Training and Technical Assistance Center
health care expenditures	total amount of money spent by state government on healthcare (in millions)	U.S. Census Bureau, Annual Survey of State Government Finances (Annual), 1997-2013