The Effects of Medical Marijuana Laws on Potency

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Introduction

Marijuana (cannabis) is the most widely used illicit substance in the United States, with about 17.4 million past-month users in 2010. Recent trends reveal an increase in marijuana prevalence, especially among younger populations. Between 1990 and 2010, rates of past-month marijuana use increased about 68% for youth aged 12-17, 46% for young adults aged 18-25, and 12% for adults aged 26-34 (Substance Abuse and Mental Health Services Administration, 2011). Over the same time period, average concentrations of Δ^9-tetrahydrocannabinol (THC)—the main psychoactive component of marijuana—nearly tripled from 3.4% to 9.6% (ElSohly, 2008, 2012). This epidemiology has important public health implications, as mounting evidence links higher potency marijuana to an array of adverse outcomes, especially among novice users (Hall and Degenhardt, 2006; McLaren et al., 2008). In particular, research supports claims of dose-dependency between THC levels and risk of acute anxiety (Crippa et al., 2009), psychosis (Di Forti et al., 2009), cognitive impairment (Ramaekers, Kuypers, and Samyn, 2006), and vehicular accidents (Li et al., 2012; Ramaekers et al., 2004).

Although there has been some recent attention given in the academic literature to the question of whether permissive state medical marijuana laws have been contributed to the recent rise in recreational use of marijuana, with results from published studies being a bit mixed (Friese and Grube, 2012; Harper, Strumpf, and Kaufman, 2012), virtually no attention has been given to the possible impact these state laws might have on consumption through their effects on the average potency of the marijuana consumed. Indeed, it is entirely possible that a rise in the potency of marijuana could be associated with a decline in total quantity of marijuana consumed, as users consuming higher potency marijuana require less marijuana to reach the same level of high.

In light of the public health concerns associated with rising rates of high-potency marijuana use, particularly among youth, and the possible mediating effect this rise would have on total marijuana consumed, an obvious question to ask before examining the impact of medical marijuana laws (MMLs) on recreational marijuana use is whether medical marijuana laws have contributed to rising potency trends over the past two decades. Although no state law directly regulates the THC content of medical marijuana, there is some evidence to suggest that the typical potency of medical marijuana is higher than that of commercial-grade marijuana sold in black markets (Burgdorf, Kilmer, and Pacula, 2011). It may be the case that the general allowance for growing high-grade marijuana for medicinal purposes—including specific rules around retail outlets or dispensaries, home cultivation, and patient caregivers—has contributed to the upward trend in potency observed in recreational markets.

The focal relationship we examine in this study, therefore, concerns the effect of state medical marijuana laws on cannabis potency in the broader marketplace. Specifically, we investigate state-level variations in potency for the years 1990-2010 using data from the University of Mississippi's Potency Monitoring Program (PMP), a federally-funded surveillance program that forensically analyzes marijuana samples seized by federal, state, and local law enforcement agencies (see Mehmedic et al., 2010). Recognizing that alternative state policies and programs may also affect potency, we explore the competing effects of rival explanatory factors including marijuana decriminalization and law enforcement efforts. In the next section, we further explicate these policies and possible mechanisms of action.

State Marijuana Policies, Markets, and Potency

Marijuana is not a uniform product, varying considerably by strain (indica, sativa, hybrid), cultivation technique (hemp, sinsemilla, hydroponic), and manner of processing (herb, resin, oil). The resulting phenotypes contribute to wide variations in potency across both time and place (Burgdorf, Kilmer, and Pacula, 2011; Slade et al., 2012). Although direct empirical evidence is limited, insider and journalistic accounts suggest that MMLs—and the medical marijuana industry built up around them—have greatly enhanced the development and diffusion of high-potency cannabis cultivars and sophisticated technologies of production (Downs, 2012; Geluardi, 2010; Rendon, 2013; West, 2011). As Rendon (2013:147) explains about developments in the earliest adopting medical marijuana state, "the legalization of marijuana for medical use in California has changed everything about the market for pot and is pushing changes for growers, breeders, and the plant itself."

Given the relatively small size of legitimate medical marijuana markets (Bowles, 2012; General Accountability Office, 2002), one possible concern regarding our hypothesized policy effect is that any potential impact will be swamped by trends in the much larger recreational market. However, if there is substantial technology and product transfer between medical and recreational marijuana markets, as we suspect, the influence of these policies will be more broadly detectable. Indeed, the available evidence suggests that the two markets are quite interrelated, especially where oversight is lax, and that substantial quantities of medical marijuana are being overproduced and diverted into recreational markets (Finlaw and Brohl, 2013; Rendon, 2013; Wirfs-Brock, Seaton, and Sutherland, 2010). A recent investigation by the Rocky Mountain High Intensity Drug Trafficking Area program, for instance, uncovered more than 70 instances of the diversion of Colorado medical marijuana by dispensaries, registered patients, and licensed caregivers (Investigative Support Center, 2012). Indicative of such leakage, recent research with in-treatment adolescents in Denver found that one-half to three-quarters had previously used diverted medical marijuana for nonmedical reasons (Salomonsen-Sautel et al., 2012; Thurstone, Lieberman, and Schmiege, 2011).

Decriminalization policies and law enforcement efforts can potentially influence potency as well, so we also assess the competing effects of these rival factors. We hypothesize that the effects of these various policies may operate, at least partly, through state-level contextual features such as the composition and size of the marijuana market. In other words, we surmise these policies help shape state markets, which in turn influence the quality and type of marijuana supplied to and demanded by users in these markets. We examine these various policies and propositions in more detail in the following sections.

Medical Marijuana Laws

Since 1996, nineteen states and the District of Columbia have adopted laws affording qualifying patients the right to possess and use marijuana for medical purposes without the threat of state prosecution and punishment.[1] Researchers have only recently begun to investigate the policy impacts of these laws. Most of these studies have focused on marijuana use, especially among youth, and in general they find no direct association between the policies and youth use (Anderson, Hansen, and Rees, 2012; Cerdá et al., 2012; Friese and Grube, 2012; Gorman and Huber, 2007; Harper, Strumpf, and Kaufman, 2012; Khatapoush and Hallfors, 2004; Wall et al., 2011). Studies considering adults have found very modest correlations (Anderson, Hansen, and Rees, Forthcoming). Other studies have examined a range of alternative outcomes, finding that

[1] We distinguish current medical marijuana laws from the more circumscribed state therapeutic research programs enacted in the 1970s and 1980s that allowed investigational access to marijuana strictly within a clinical research setting.

MMLs are not significantly related to emergency department visits (Gorman and Huber, 2007) and positively related to marijuana prices (Pacula et al., 2010) and possession arrests (Chu, 2012), with mixed results on treatment service utilization (Anderson, Hansen, and Rees, 2012; Chu, 2012), and even apparent benefits with respect to suicide rates (Anderson, Rees, and Sabia, 2012) and alcohol-related traffic fatalities (Anderson, Hansen, and Rees, Forthcoming). However, to date, all of these studies have grouped medical marijuana laws as homogenous policies, ignoring the extent to which particular aspects of state laws (e.g., allowance of dispensaries) have influenced these results (Pacula et al., 2013).

As of 2012, twelve states had implemented, or were in the process of establishing, state-licensed medical marijuana dispensary systems. Marijuana supplied under a state-sanctioned distribution regime is likely to be relatively more potent and of consistently higher quality than marijuana available on the black market. In the Netherlands, for instance, marijuana sold through coffee shops and pharmacies for recreational and medical use, respectively, is more potent on average than marijuana available in the illicit markets of neighboring countries (Hazekamp, 2006; King, Carpentier, and Griffiths, 2004; Pijlman et al., 2005). In Switzerland, Killias et al. (2011) report that the mean THC content of recreational marijuana dropped from 15.7% (range: 7.9 - 28.4%) to 12.0% (range: 3.7 - 17.6%) between 2004 and 2009 after the government shut down previously tolerated retail cannabis shops. As these examples suggest, average marijuana potency will likely be greater under a regime that sanctions or tolerates the retail distribution of marijuana, probably due to greater quality control, efficiency gains in production, and reduced enforcement risks.

Home cultivation currently offers another supply option in fifteen medical marijuana states. These policies might promote the production of less potent marijuana if the majority of patients, especially those who are seriously ill, lack the necessary amenities, resources, or skills to cultivate and maintain their own supply of medical-grade marijuana (Chapkis and Webb, 2008; Feldman and Mandel, 1998). There is evidence to suggest that some medical marijuana patients actually prefer lower-THC cannabis because it treats their symptoms without the accompanying psychoactive high (Downs, 2012; Harris et al., 2000; Swift, Gates, and Dillon, 2005). Drawing again on studies from Europe, surveys of Belgian, Danish, and Finnish home cultivators suggest that the strength of this preference may be related to the perceived potency of marijuana that is available from other sources (Decorte, 2010; Hakkarainen et al., 2011). In Finland, for instance, where marijuana production and distribution is illegal for any purpose, few home cultivators (2.3%) reported growing their own marijuana specifically because they viewed black-market product as being too potent. However, in Belgium, where neighboring Dutch coffee shops afford ready access to high-potency marijuana, one in five (19.5%) home cultivators grew marijuana because other (i.e., coffee shop) marijuana was viewed as too potent or 'worked up.' In short, home cultivation policies might foster the cultivation of lower-potency marijuana due to the proclivities of home growers, especially when high-potency marijuana saturates other sources of supply.

Certain provisions governing home cultivation might alternatively encourage the production of higher-potency marijuana. For example, current state limits on the number of home-cultivated plants range from 3 to 24. In direct response to the lower limits, master growers have developed and promulgated advanced cultivation methods that aim to maximize the potency and yield of each homegrown plant (West, 2011). States with home cultivation policies also permit designated caregivers to grow marijuana for patients. Most states limit the number of patients per caregiver to between one and five, although two states—California and Nevada—

currently have no patient caps. High or nonexistent limits on the number of patients per caregiver opens the door to potential abuses. For example, in Montana the lack of patient limits led many entrepreneurial providers to open storefront dispensaries that simultaneously catered to hundreds of patients (Scott, 2010). Thus, specific home cultivation provisions concerning plant and patient limits, in concert with dispensary regulations, may differentially incentivize the production of medical marijuana with higher or lower concentrations of THC.

Marijuana Decriminalization Policies

Since the 1970s, 16 states have formally decriminalized marijuana by removing penalties for possessing small amounts of marijuana intended for personal use.[2] Many studies have investigated the effects of these policies on marijuana use, and the empirical evidence remains quite mixed (Damrongplasit and Hsiao, 2009; Pacula, Chriqui, and King, 2004). However, no studies have directly examined the effect of marijuana decriminalization on potency, so we can only speculate about possible impacts. As with medical marijuana legalization, there are plausible mechanisms through which decriminalization might increase or decrease average potency. If decriminalization leads to higher demand and a more stable market, growers may be more willing to invest in advanced production technologies that facilitate the cultivation of higher-potency marijuana, or they may wish to grow a more potent cultivar as a means of product differentiation. On the other hand, because current laws assign sanctions for marijuana possession based upon the weight of the amount seized rather than the THC content, existing rules implicitly encourage users to purchase higher potency products. Decriminalization might

[2] More recently, states have begun exploring outright legalization of marijuana, with Washington and Colorado passing legalization measures in November 2012. These laws are not yet fully implemented, so we do not discuss the implications here. See Caulkins, Lee and Kasunic (2012) for a discussion of the general policy implications and consequences of these measures.

induce consumers to more readily accept low-potency variants. More generally, if consumers are heterogeneous in their potency preferences, users might respond by purchasing less expensive (and presumably less potent) forms of marijuana (Kleiman, 1989).

Marijuana Enforcement and Eradication Programs

Research in different contexts suggests that targeted drug law enforcement operations aimed at increasing seizures and arrests produce few sustained changes in price, purity, or availability in street-level drug markets (Best et al., 2001; Ciccarone, Unick, and Kraus, 2009; Dobkin and Nicosia, 2009; Weatherburn and Lind, 1997). The one study that examined outcomes in marijuana markets (Best et al., 2001) found that the majority of drug users perceived no changes in marijuana quality during the two-week period following a police crackdown. This is probably least surprising for marijuana, since it takes time for existing stocks to be depleted. Moreover, dealers cannot readily "cut" marijuana as they can with heroin and cocaine.

Over the longer-term, other studies have found positive associations between mandatory sentencing laws and heroin and cocaine purity (Davies, 2010) and precursor control laws and methamphetamine purity (Nonnemaker, Engelen, and Shive, 2011). As Nonnemaker et al. (2011) suggest, this counterintuitive finding may be the consequence of an adaptive response by traffickers to seek higher-quality international sources of supply. Marijuana markets have undergone a more protracted transformation (Szendrei, 1997), with supply-side marijuana enforcement and eradication efforts viewed as a key driver of this process (United Nations Office on Drugs and Crime, 2006). According to this argument, the marijuana industry adapted to greater law enforcement pressure, first, by shifting from foreign to domestic production in the 1970s and early 1980s as importation became increasingly risky and, second, by relocating domestic production indoors beginning in the mid-1980s to reduce risk of detection and seizure from expanding stateside eradication programs. These developments may have spurred increases in marijuana potency as production moved closer to consumers and domestic growers mastered progressively sophisticated indoor cultivation techniques (e.g., hydroponics, cloning) that maximized per-plant potency, yields, and profits (Bouchard and Dion, 2010; Potter, Gaines, and Holbrook, 1990; Reinarman, 2009).

Aggregate Market Effects: An Intervening Variable Hypothesis

The mix of state marijuana policies governing medical use, decriminalization, and enforcement can be expected to influence potency in a number of cross-cutting ways. It is important to reiterate, however, that none of these laws and programs explicitly target or place limits on potency. Rather, the policies more directly target the structure and organization of the marijuana marketplace—whether by allowing medical use and related distribution for a clinical population, tolerating recreational use more broadly, or curtailing local illicit production and distribution. Such market shifts could manifest in a variety of ways, including the methods and modes of production, legal and illegal points of distribution, the types and forms of available marijuana, the actors and organizations involved, the presence of ancillary industries and services (e.g., agricultural supply stores), and prices. These various market structures are, in turn, likely to have a direct impact on potency. Thus, we suspect state marijuana policies will more strongly influence potency *indirectly* through their market-shaping effects. In other words, we hypothesize that changes in the size and composition of marijuana markets serve as an alternative causal path through which state policies exert their influence on potency.

Methods

Data

The measures for this study come from several data sources. Marijuana potency and state-level market indicators were derived from the University of Mississippi's Potency Monitoring Program (PMP), a federally-funded forensic surveillance program that analyzes seized marijuana samples (see Mehmedic et al., 2010). The micro-level PMP data used for the current study comprise n = 39,157 observations of "nondomestic" herbal marijuana seized by law enforcement in the 50 U.S. states and the District of Columbia over the 1990-2010 study period. According to PMP analysts, so-called nondomestic samples exclude seizures made from active growing operations, yet "could possibly have been produced in the United States prior to seizure" (Mehmedic et al., 2010:1214). Herbal marijuana includes samples identified as either sinsemilla, commercial-grade, or kilobrick, but excludes ditchweed, hashish, and hash oil. Sinsemilla, meaning without seeds, refers to the buds of unpollinated female plants cultivated for high THC content. Commercial-grade refers to mass-produced marijuana of lower quality. Kilobrick refers to commercial-grade marijuana of (typically) Mexican origin, compressed into bricks for transport to the United States.

Despite their potential utility for the current study, the PMP data have a number of important limitations. First, as shown in appendix Table A1, the n = 39,157 samples populate 950 of a possible 1,071 state-year cells (88.7%) with an average of 41.2 (SD = 114.5) observations per populated cell, indicating an unbalanced dataset with wide variability in data saturation at the state-year level. Second, even with the available data, they reflect a nonrandom sample of law enforcement seizures, and therefore might not be representative of the marijuana available to consumers. Third, the general quality or freshness of the analyzed marijuana has improved over time due to shifts in the market (from foreign to domestic sources) and decreases in seizure to analysis time (Sevigny, 2013), although this is less of a concern for the data years analyzed in this study. Despite these limitations, the PMP data represent the only available comprehensive dataset on U.S. potency trends.

We merged state-year policy, enforcement, and demographic variables with the PMP data. State medical marijuana and decriminalization policy variables were coded using a previously developed legal database protocol (Pacula et al., 2002), adapted and updated for the current study. Marijuana enforcement indicators were derived from the Domestic Cannabis Eradication/Suppression Program (DCE/SP) (Drug Enforcement Administration, 2013). Although DCE/SP participation and reporting may vary by state (Office of the Inspector General, 1995), this is the only national program that provides data on enforcement activity against marijuana growers and producers. Finally, demographic covariates were obtained from the CDC WONDER online database (Centers for Disease Control and Prevention, 2013).

Measures

The dependent variable, *THC %*, measures the concentration of Δ^9-tetrahydrocannabinol by weight in the seized PMP samples. This measure is fully reported in the PMP dataset for all observations during the study period.

The focal independent variables include laws regulating access to medical marijuana. In addition to a general *medical marijuana law* indicator, we created policy variables capturing additional aspects of these laws. In each case, the indicator was "turned on" for a given year if its effective date occurred prior to July 1^{st}; otherwise, the law was activated for the following calendar year. *Licensed dispensaries* equals one if the state law explicitly allows retail sales of marijuana *and* the regulatory and distribution regime was in place and operational. Given that the actual process of implementing a dispensary system can take years, this rule ensures that we are measuring actual policy changes. In a handful of states that do not explicitly permit retail sales, dispensaries have opened nonetheless due to legal loopholes. To capture this quasi-legal policy environment, we also code *active dispensaries* equal to one if the state has a functional dispensary system, officially sanctioned or otherwise. *Home cultivation* is set equal to one if qualified patients are allowed to grow their own personal supply of marijuana. *Plants per patient* codes the total number of marijuana plants that patients (or their designated caregivers) are allowed to cultivate at any one time. This measure was set to zero if the state does not permit home cultivation, and capped at fifty if the state declares no statutory limits (or roughly twice the highest state limit of twenty-four). *Patients per caregiver* codes the number of patients for whom a designated caregiver can grow marijuana. Similarly, this measure was set to zero if home cultivation is not allowed, and capped at ten if the state sets no limits (or twice the highest state limit of five). See Table 1 for a state-by-state description of these laws and our coding of them.

A set of rival independent variables captures state decriminalization policies and marijuana enforcement efforts. *Decriminalization policy* equals one if the state has removed criminal penalties for the possession of small amounts of marijuana intended for personal use.[3] State marijuana enforcement activity, as reported by the Domestic Cannabis Eradication/Suppression Program, is operationalized as *log outdoor plots seized* and *log indoor grows seized per 100,000 population* (adding a constant of one prior to log transformation). Note that eradication data for the District of Columbia are missing because it does not participate in

[3] The following states were coded as having a decriminalization policy beginning in the year indicated (or 1990 if earlier): Oregon (1973), Alaska (1975), Colorado (1975), California, (1975), Maine (1975), Minnesota (1976), Ohio (1976), Mississippi (1977), Nebraska (1977), New York (1977), North Carolina (1977), Arizona (1995), Nevada (2002), Massachusetts (2009). In addition, although they fall outside the study period, Connecticut (2011) and Rhode Island (2013) have recently decriminalized marijuana.

the DCE/SP. According the National Drug Intelligence Center (2002:18), "cannabis is not cultivated in large quantities in D.C., primarily because the urban landscape is not conducive to outdoor grows." Thus, we assumed the annual number of outdoor plots seized was zero over the study period. Alternatively, for indoor grows seized, we employed single hotdeck imputation to fill in missing data from donor observations chosen at random.[4]

Aggregate marijuana market characteristics at the state-year level measure the broader context through which state policies are hypothesized to exert an indirect effect on potency. While not perfect, we use aggregated statistics from the PMP to capture elements of the aggregate market. We recognize that these aggregate statistics are potentially biased, as they could simply reflect priorities of law enforcement rather than the true evolution of the market itself. This would be a problem if law enforcement differentially changed its focus on, say, indoor grows over time in response to medical marijuana laws. If the medical marijuana market supplies the recreational market, however, then this change in enforcement priorities might be consistent with a true shift in the recreational market. Moreover, for the purposes of this analysis, even if these aggregate marijuana market measures are affected predominantly by law enforcement priorities they would to some extent capture the dimension of interest to us, as we are fundamentally interested in understanding the extent to which the policy might impact the market through either natural supply changes or changes in enforcement patterns (and hence legal risk). Thus, we go ahead and use these measures to help us consider the possible indirect effect of the policy on potency.

As noted above, marijuana comes in different forms (i.e., sinsemilla, commercial-grade, kilobrick), and the relative share of these forms as measured by PMP captures compositional effects of the marijuana marketplace. Thus, both *sinsemilla %* and *commercial-grade %* quantify

[4] We have a standing FOIA request with the DC Metropolitan Police Department to obtain this data.

the percentage of seizures for these respective product types by state-year (with *kilobrick %* serving as the reference category). We also attempt to measure the aggregate size of the marijuana market by state-year, using an indicator of the *log total kilograms seized* (adding a constant of one prior to log transformation). While we recognize that seizures are a function of both law enforcement effort as well as the amount of the product trading in the market, we believe that accounting for the overall seizure amount can be a useful proxy of market size within a given state-year. Note that *n* = 613 observations (1.6%) were missing quantity information, so these samples did not factor into the calculation of the total.

Finally, we include covariates for demographic characteristics at the state-year level. Specifically, we operationalized measures for *percent non-Hispanic white*, *percent aged 20-29*, *percent aged 30-59*, and *percent aged 60+* (with *percent aged 0-19* serving as the reference category).

Empirical Approach

We employ a mediator model within a differences-in-differences linear regression framework to estimate the direct and indirect effects of MMLs on potency for the 50 U.S. states and the District of Columbia over the period 1990-2010. The unit of analysis is the individual seized marijuana specimen. We weighted the analyses by the inverse of the variance of the observed THC percentage by state-year, which gives more weight to state-years measured with greater precision and a larger number of observations. For the *n* = 78 state-years with a single observation and thus no within-cell variation, weights were defined by approximate state-decade cells with years collapsed into two periods: 1990-1999 and 2000-2010. To control for potential heteroskedasticity and serial correlation in errors, we clustered standard errors by state (Bertrand, Duflo, and Mullainathan, 2004).

The basic specification of the differences-in-differences OLS regression model is as follows:

$$THC\%_{ist} = \alpha + \tau MML_{st} + \omega Z_{st} + \beta X_{st} + \gamma_s + \theta_t + \varepsilon_{ist} \quad (1)$$

where $THC\%_{ist}$ is the potency of seizure *i* in state *s* during year *t*. The focal policy indicator MML_{st} captures whether a medical marijuana law was operational in state *s* and year *t*. The vector Z_{st} includes the rival independent variables (i.e., marijuana decriminalization and eradication activity), and the vector X_{st} includes observed state-level demographic controls for state *s* and year *t*. Finally, state fixed effects (γ_s) and year fixed effects (θ_t) control for potential unobserved confounders that are invariant across jurisdiction and time. This specification essentially implements a before and after design with an untreated control group, comparing within-state changes in potency pre and post MML adoption to potency changes in states that did not adopt such a law (Angrist and Pischke, 2009; Bertrand, Duflo, and Mullainathan, 2004; Meyer, 1995; Wooldridge, 2010). The coefficients for the rival independent variables are interpreted in the same way, although the enforcement variables measuring indoor and outdoor eradication reflect "intervention intensity" rather than the effect of a discrete policy change (Angrist and Pischke, 2009; Wooldridge, 2010).

In a mediation context, Equation (1) estimates the *total effect*, τ, of MML on THC% (Baron and Kenny, 1986; MacKinnon, 2008). This total effect can be parceled into an *indirect effect*, which reflects the influence of MMLs on potency operating through the context of the broader marketplace, and a *direct effect*, which estimates the relation of MMLs to potency not mediated through these ecological factors. With a single mediator, parceling the total effect, τ, of

MMLs on potency begins by estimating the direct effect, $\acute{\tau}$, of the law per the following equation:

$$THC\%_{ist} = \alpha + \acute{\tau} MML_{st} + \omega Z_{st} + \delta M_{st} + \beta X_{st} + \gamma_s + \theta_t + \varepsilon_{ist} \quad (2)$$

where M_{st}, the intervening variable for state *s* and year *t*, has been added to Equation (1). We then estimate the indirect effect, $\tau - \acute{\tau}$, as the difference between the coefficients for the total effect and the direct effect (Clogg, Petkova, and Cheng, 1995; MacKinnon et al., 2002). In similar fashion, we also decompose the total effects of the rival independent variables held in Z_{st}. Furthermore, because we are investigating the effects of multiple mediators, we repeat this series of estimation steps by entering market composition (sinsemilla %, commercial-grade %) and size (log total kilograms seized) variables in M_{st} both separately and jointly (MacKinnon, 2008). All analyses were conducted using Stata MP 12.1.

Results[5]

Table 2 presents weighted descriptive statistics for the pooled sample. The mean potency is about 4.3% THC, with wide variation across observations. About 5% of the observations were seized in medical marijuana states, compared to 39% for decriminalization states. The relatively low rate of observations in medical marijuana states is a function of both the weighting and the long time period than it is a low absolute number of observations in medical marijuana states. Relatively more outdoor plots than indoor grows were seized during the study period. Aggregate characteristics show that marijuana markets were typically dominated by commercial-grade product, with sinsemilla representing a rather small share of these markets over time, but also

[5] Note to discussant: On the final iteration of this paper, we will be conducting many sensitivity analyses. If you have any particular thoughts concerning methods or approach, please comment.

that there is wide variability in marijuana composition across state-years. The overall size of the markets also varied considerably by state-year.

The differences-in-differences OLS estimates are presented in Table 3, with five models that sequentially elaborate additional sets of controls. Model (1) depicts the simple bivariate model, demonstrating significant positive variation between medical marijuana laws and potency. Model (2) adds state and year fixed effects, indicating that controlling for unobserved unit and time constant factors reduces the overall MML effect, but it nevertheless remains significant and positive. Model (3) adds observable state-year demographic controls, which have little explanatory power above and beyond the state and year fixed effects. In model (4), we add the decriminalization policy variable, which slightly increases the MML effect size. This suggests possible confounding as decriminalization is positively associated with both potency and the likelihood of MML adoption. With the addition of the two marijuana eradication variables, model (5) presents our fully elaborated model that controls for rival factors as well as observable and unobservable covariates. The inclusion of these additional variables does not change the magnitude of the coefficient from the previous three specifications, and the coefficient remains statistically significant at the 5% level. Thus, we see that over time MMLs significantly increase average potency by about one percentage point THC by weight. Although enforcement does not appear to influence potency in our sample (to the extent that it is captured by the seizures), states with decriminalization policies were associated with an average 1.4 percentage point increase in potency over time. It is unclear whether these increases are sizable enough in practical terms to negatively impact other public health outcomes (e.g., drugged driving accidents, hospital admissions), but the combination of decriminalization and medical marijuana laws does appear to produce meaningful increases in potency in these states over time.

Next, we examine the mediating effects of contextual market factors on the effects of medical marijuana laws on potency. These results are presented in Table 4 in three panels, where we introduce compositional effects in Panel A, size effects in Panel B, and both groups of effects in Panel C. In each case, the total effects for the focal and rival independent variables from model (5) in Table 3 are presented first. In Panel A, after including aggregate marijuana market variables for sinsemilla % and commercial-grade %, we observe that the direct effect of MMLs becomes relatively small and insignificant ($\beta = 0.30$, n.s.), whereas the indirect effect is relatively larger and significant ($\beta = 0.69$, $p = 0.017$). In other words, the effect of MMLs on potency operates primarily through the compositional features of the marketplace to create a conducive environment for the production and distribution of high-potency sinsemilla. Lastly, it is notable that none of the rival factors, in particular marijuana decriminalization, operate indirectly through the marketplace variables that we are able to measure.

In Panel B, where we introduce the mediator for market size, we see a different pattern of results indicating a suppression effect for both medical marijuana and decriminalization policies. In other words, these more liberal policies appear to increase the overall size of the market as measured by quantity, but a larger market in turn increases the saturation of lower-THC marijuana. When we control for both sets of mediators in Panel C, we see that the larger, more significant mediating effects derive from compositional rather than size factors.

In Table 5, we report results examining the effects of specific medical marijuana law provisions, while controlling for rival independent variables.[6] We begin by sequentially introducing key aspects of MMLs. Model (1) shows the effect of licensed dispensaries on potency, indicating that over time states that adopt this type of supply mechanism have THC

[6] Note that we do not present a mediator model for specific medical marijuana provisions as the results and conclusions do not change from the base model using the general medical marijuana law indicator.

levels about 1.5 percentage points higher on average. This effect is picking up the influence of California primarily, so model (2) which includes an indicator for active dispensaries, legal or not, may provide a more representative assessment of this supply option. Although the effect is about half that for licensed dispensaries, it remains positive and statistically significant. Home cultivation (model [3]) reveals an effect very similar to the general MML indicator, which is not surprising given that Maryland is the only state in our observation period to not have a home supply mechanism (or any supply mechanism for that matter). When we examine the influence of plant and patient limits in models (4) and (5), respectively, we find no significant effects for these aspects of medical marijuana laws on potency. Lastly, in model (6) when we control for licensed dispensaries and home cultivation simultaneously, both effects remain positive and significant.

Discussion

A fundamental question that has of yet remained unanswered in the academic literature is whether state medical marijuana laws lead to a rise in the average potency of marijuana available on the market. Indeed, prior research by Pacula et al (2010), which examined the impact of medical marijuana laws on self-reported price paid per gram among the arrestee population in the 2000-2003 Arrestee Drug Abuse Monitoring (ADAM) data, showed that self-reported marijuana prices were indeed higher in states that had adopted medical marijuana laws than those states that did not, which the authors interpreted as evidence of a demand shift. It is also possible, however, that the rise in price is indicative of a higher average potency available on the market. Indeed such an interpretation is entirely consistent with journalistic accounts of the impact of these laws on development and diffusion of high-potency cannabis cultivation techniques (Downs 2012;

Geluardi 2010; Rendon, 2013; West 2011). This paper provides a more direct assessment of the impact of these state medical marijuana laws on the potency of marijuana seized through regular law enforcement activities. The paper provides compelling evidence that the average potency of marijuana seized by law enforcement personnel increases on average by 1 percentage point after legalization of marijuana medical marijuana. Moreover, when we examined specific medical marijuana provisions, our results suggested that states that allow both dispensaries and home cultivation have an even higher average potency, which suggests that these allowances may enable the open discussion, development, and diffusion of high-potency cultivation techniques. Future research will need to confirm this finding using additional years of data that include more than just two legal dispensary states.

While we recognize the potential endogeneity of the aggregate marijuana market measures to enforcement priorities, our mediational analyses examining the mechanism through which medical marijuana laws influence potency suggest that the impact of these laws on potency occurs predominantly through a compositional shift in the share of the market captured by high-potency sinsemilla. In other words, the policies appear to have the greatest influence in the type of marijuana sold in a given market more than they influence the average potency of the same type of marijuana sold. Decriminalization, in contrast, is more directly associated with increases in potency.

This study has a number of important limitations. First, the primary source of information on marijuana potency comes from law enforcement data. We do not have a random sample, and to the extent that law enforcement data is systematically biased toward those more engaged or invested in the marijuana trade, these findings might not hold for the overall recreational marijuana market as a whole. This is particularly true of states with relatively few potency observations. Moreover, our compositional measures of the aggregate marijuana market are potentially even more susceptible to bias caused by purposeful law enforcement strategies. It would be important to see if future work using data from another source validate our findings here, although we are unaware of any other publicly available source of marijuana potency data in both medical marijuana states and nonmedical marijuana states.

Second, it is very difficult in our data to tease out independent effects of particular elements of the state policies and a broad medical marijuana policy itself, as many of the policies tend to have very similar characteristics (e.g. allowing for home cultivation). Variation in key characteristics stems largely from just a few unique states, and hence results from these analyses may not be fully generalizable. This is perhaps less true for states with active dispensaries, which have indeed evolved somewhat organically over time.

Finally, it should be reiterated that none of the state policies we examined explicitly specified a maximum potency that could be sold or any guidelines for potency in general. To the extent that medical marijuana laws emerge that provide greater specificity regarding the allowable amount of THC in medical-grade marijuana, it is possible that the impact of this policy could change over time.

Should the findings from this study be replicated, the results have very important implications for policymakers and those in the scientific community trying to interpret the literature of the effects of MMLs on marijuana use. In particular, even if medical marijuana policies do not lead to an increase in the prevalence of marijuana use, they may still harm public health by encouraging the use of higher potency marijuana and increasing the risk of drugged driving, drug-induced psychoses, and perhaps dependence. These results suggest that future work should reconsider the impact of MMLs on health outcomes, paying particular attention to policies that enable active or licensed dispensaries or home cultivation, as these are a key policy elements that seemingly influence potency above and beyond the general allowance for medical marijuana itself.

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Table 1. State Medical Marijuana Laws and Coding, 1990-2010

State	MML Effective Year[a]	Dispensaries: Licensed[b]	Dispensaries: Unregulated[c]	Home Cultivation	Plants per Patient[d]	Patients per Caregiver[e]
Alaska	1999	No	No	Yes	6	1
California	1997	Yes (2004)	Yes (1996)	Yes	50 12 (2004)	10
Colorado	2001	No	Yes (2005)	Yes	6	5 10 (2008)
Hawaii	2001	No	No	Yes	7	1
Maine	2000	No	No	Yes	6	10 5 (2010)
Maryland	2004	No	No	No	0	0
Michigan	2009	No	Yes (2009)	Yes	12	5
Montana	2005	No	Yes (2009)	Yes	6	10
Nevada	2002	No	No	Yes	7	1
New Mexico	2008	Yes (2010)	No	Yes	16	4
Oregon	1999	No	No	Yes	7 24 (2006)	4
Rhode Island	2006	No	No	Yes	12	5
Vermont	2005	No	No	Yes	3 9 (2008)	1
Washington	1999	No	Yes (2009)	Yes	50 15 (2009)	1

[a] The indicated year reflects the year of adoption if the effective date occurred prior to July 1st; otherwise, the following calendar year is indicated. The following states adopted an effective law after 2010: Arizona, Connecticut, Delaware, District of Columbia, Massachusetts, and New Jersey.
[b] The following states either adopted licensed dispensary provisions post 2010 or they were not yet active: Colorado, Maine, Rhode Island, Vermont.
[c] Oregon is currently known to have unregulated dispensaries, but we could not confirm that these dispensaries opened during or prior to 2010.
[d] This measure codes total, not just mature, plants allowed. States without a statutory or administrative limit were coded 50. Revised limits and the effective year of the change are also indicated. California allows higher limits per local ordinance, and Colorado provides an affirmative defense for cultivating more plants.
[e] States without a statutory or administrative limit were coded 10. California set a limit of one, but this only applies to patients and caregivers not living in the same county. Limits in Montana have been recently codified, but court injunctions have prevented implementation. Washington's limit of one has been loosely interpreted to mean one patient at any given time, encouraging some caregivers to actually care for hundreds of patients.

Table 1. Descriptive Statistics, Pooled Sample (N = 39,157), 1990-2010

Variable	Mean	SD	Min	Max
THC %	4.34	2.93	0.01	37.2
Medical Marijuana Law	0.05	0.22	0	1
Licensed Dispensaries	0.01	0.10	0	1
Active Dispensaries	0.04	0.19	0	1
Home Cultivation	0.05	0.22	0	1
Plants per Patient	1.73	8.67	0	50
Patients per Caregiver	0.41	1.93	0	10
Decriminalization Policy	0.39	0.49	0	1
Log Outdoor Plots Seized per 100,000 Population	1.65	1.08	0	7.96
Log Indoor Grows Seized per 100,000 Population	0.68	0.47	0	3.18
Sinsemilla %	4.00	12.59	0	100
Commercial-Grade %	49.24	29.90	0	100
Log Total Kilograms Seized	8.30	3.24	0.08	12.07
Non-Hispanic White %	62.04	14.91	26.39	98.22
% Aged 20-29	15.07	1.41	10.87	22.24
% Aged 30-59	40.00	1.48	32.37	46.25
% Aged 60+	15.45	2.21	6.64	23.49

Note: Statistics are weighted by the inverse of the variance of THC % by state-year cells.

Table 3. Differences-in-Differences OLS Estimates of Effect of Medical Marijuana Laws on Potency (THC %), 1990-2010

	(1)	(2)	(3)	(4)	(5)
Medical Marijuana Law	3.32 (0.68)***	0.97 (0.36)**	0.92 (0.37)*	1.03 (0.34)**	0.99 (0.41)*
Decriminalization Policy				1.40 (0.26)***	1.41 (0.29)***
Log Outdoor Plots Seized per 100,000 Population					0.14 (0.17)
Log Indoor Grows Seized per 100,000 Population					0.04 (0.16)
Constant	4.16 (0.18)***	3.25 (0.29)***	-21.27 (13.27)	-28.57 (11.52)*	-32.09 (12.63)*
State Fixed-Effects	No	Yes	Yes	Yes	Yes
Year Fixed-Effects	No	Yes	Yes	Yes	Yes
Demographic Covariates	No	No	Yes	Yes	Yes
Adj. R^2	6.4%	34.1%	34.7%	34.9%	34.9%

Note: Estimates are weighted by the inverse of the variance of the response variable by state-year cells. Cluster robust standard errors are reported. N = 39,157 for all models.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 4. Mediator Model for Differences-in-Differences OLS Estimates of Effect of Medical Marijuana Laws on Potency (THC %), 1990-2010

	Total Effects	Direct Effects	Indirect Effects
Panel A	(*c*)	(*c′*)	(*c* - *c′*)
State Policies			
Medical Marijuana Law	0.99 (0.41)*	0.30 (0.20)	0.69 (0.29)*
Decriminalization Policy	1.41 (0.29)***	1.37 (0.13)***	0.05 (0.22)
Log Outdoor Plots Seized per 100,000 Population	0.14 (0.17)	0.04 (0.12)	0.11 (0.08)
Log Indoor Grows Seized per 100,000 Population	0.04 (0.16)	0.04 (0.13)	0.00 (0.09)
Market Characteristics			
Sinsemilla %		0.07 (0.01)***	
Commercial-Grade %		-0.00 (0.00)	
Constant	-32.09 (12.63)*	-26.21 (8.61)**	
Adj. R^2	34.9%	37.5%	
	Total Effects	Direct Effects	Indirect Effects
Panel B	(*c*)	(*c′*)	(*c* - *c′*)
State Policies			
Medical Marijuana Law	0.99 (0.41)*	1.17 (0.35)**	-0.18 (0.07)**
Decriminalization Policy	1.41 (0.29)***	1.59 (0.27)***	-0.18 (0.05)***
Log Outdoor Plots Seized per 100,000 Population	0.14 (0.17)	0.14 (0.16)	0.01 (0.02)
Log Indoor Grows Seized per 100,000 Population	0.04 (0.16)	0.06 (0.15)	-0.02 (0.02)
Market Characteristics			
Log Total Kilograms Seized		0.15 (0.03)***	
Constant	-32.09 (12.63)*	-36.52 (11.86)**	
Adj. R^2	34.9%	35.2%	
	Total Effects	Direct Effects	Indirect Effects
Panel C	(*c*)	(*c′*)	(*c* - *c′*)
State Policies			
Medical Marijuana Law	0.99 (0.41)*	0.39 (0.22)	0.60 (0.30)*
Decriminalization Policy	1.41 (0.29)***	1.44 (0.13)***	-0.03 (0.22)
Log Outdoor Plots Seized per 100,000 Population	0.14 (0.17)	0.03 (0.12)	0.11 (0.08)
Log Indoor Grows Seized per 100,000 Population	0.04 (0.16)	0.05 (0.12)	-0.01 (0.08)
Market Characteristics			
Sinsemilla %		0.07 (0.01)***	
Commercial-Grade %		-0.00 (0.00)	
Log Total Kilograms Seized		0.07 (0.03)**	
Constant	-32.09 (12.63)*	-28.24 (8.30)***	
Adj. R^2	34.9%	37.6%	

Note: Estimates are weighted by the inverse of the variance of the response variable by state-year cells. Cluster robust standard errors are reported. N = 39,157 for all models. All models include state and year fixed effects and demographic covariates.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 5. Differences-in-Differences OLS Estimates of Effect of Medical Marijuana Law Provisions on Potency (THC %), 1990-2010

	(1)	(2)	(3)	(4)	(5)	(6)
State Policies						
Licensed Dispensaries	1.46 (0.55)**					1.08 (0.41)*
Active Dispensaries		0.74 (0.37)[a]				
Home Cultivation			0.94 (0.38)*			0.78 (0.33)*
Plants per Patient				0.01 (0.01)		
Patients per Caregiver					0.08 (0.04)	
Decriminalization Policy	1.31 (0.31)***	1.36 (0.31)***	1.39 (0.29)***	1.31 (0.32)***	1.38 (0.31)***	1.41 (0.29)***
Log Outdoor Plots Seized per 100,000 Population	0.16 (0.18)	0.15 (0.18)	0.14 (0.18)	0.18 (0.18)	0.15 (0.18)	0.12 (0.18)
Log Indoor Grows Seized per 100,000 Population	-0.02 (0.16)	0.02 (0.16)	0.03 (0.16)	0.01 (0.16)	0.02 (0.16)	0.03 (0.16)
Constant	-29.01 (12.80)*	-33.25 (13.48)*	-31.16 (13.08)*	-36.67 (14.36)*	-32.42 (13.57)*	-25.97 (12.42)*
Adj. R^2	34.8%	34.8%	34.9%	34.7%	34.8%	35.0%

Note: Estimates are weighted by the inverse of the variance of the response variable. Cluster robust standard errors are reported. All models include state and year fixed effects and demographic covariates.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, [a] $p = 0.051$

Table A1. Observed THC % and Number of Observations by State and Year

State		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Alabama	%		2.6		4.0	0.7	3.2	3.1	5.6	5.5	2.3	4.0		4.7	4.0	4.2		6.0	6.5	8.2	7.6	4.8	4.2
	N	0	8	0	5	1	3	3	3	1	9	3	0	3	2	6	0	1	4	2	4	2	60
Alaska	%			10.0	1.8				10.0	6.4	10.2	1.1	5.1	5.2	14.3	13.3	4.4	12.0	6.9	12.9	12.3	10.5	9
	N	0	0	14	1	0	0	0	1	3	2	3	8	2	5	2	8	12	9	6	3	7	86
Arizona	%	4.4	3.5	3.4	4.3	4.6	4.6	4.6	7.0	6.3	6.4	7.3	8.3	8.3	8.2	8.6	8.1	10.6	9.6	9.4	9.5	9.2	5.9
	N	187	209	266	203	213	260	34	63	46	59	80	64	26	66	72	84	51	85	79	91	66	2,304
Arkansas	%			3.0					4.2	7.8	3.6	2.0	5.6		6.0	4.3	3.8	6.5	6.0		15.3	8.4	6.7
	N	0	0	6	0	0	0	0	1	1	2	2	2	0	4	1	1	2	3	0	5	5	35
California	%	3.7	3.4	3.0	3.7	3.8	3.9	4.5	5.0	5.1	5.3	5.1	6.0	7.4	6.7	7.9	8.3	9.8	11.1	10.9	9.6	10.8	5.8
	N	306	482	909	912	1,139	2,358	347	333	328	395	326	426	305	263	273	489	548	523	499	343	573	12,077
Colorado	%	2.1	3.7	4.5	3.7	3.1	3.4	4.8	4.9	5.6	5.4	6.2	7.1	7.1	8.0	8.3	6.6	10.5	10.6	12.1	9.5	13.8	7.3
	N	4	3	9	21	25	12	30	27	35	32	18	15	45	20	43	11	8	9	43	49	24	483
Connecticut	%	2.0	2.2	1.3	2.6	2.7	0.6	4.9	4.4	3.8	2.6	7.5	10.7	9.4	6.5	7.0	7.3	8.5	10.4	9.2	10	13.7	6.2
	N	7	14	11	4	3	1	10	7	9	14	3	11	10	5	6	17	8	6	14	9	5	174
Delaware	%		1.9				3.3		4.4	4.0	5.0	6.9	5.5	5.0	7.2	10.5	11.8	7.7	11.7	8.2	12.9	12.2	9.2
	N	0	2	0	0	0	1	0	5	6	3	8	2	1	3	13	11	2	11	6	6	12	92
District of Columbia	%		0.3			3.9	3.0	4.2	4.6	4.4	4.7	5.4	5.6	6.5	7.3	7.9	8.2	8.7	9.2	9.6	9.0	10.6	6.3
	N	0	1	0	0	1	39	124	89	86	143	130	102	112	108	104	95	83	61	55	16	14	1,363
Florida	%	4	3.6	3.4	3.8	3.5	4.2	5.0	5.2	4.3	5.4	5.0	7.0	5.6	6.2	7.6	5.7	7.1	8.5	7.7	8.1	9.8	6.2
	N	44	75	145	89	79	99	70	96	80	95	98	78	95	137	142	162	200	190	182	113	145	2,414
Georgia	%	2.2	2.7	2.9	4.3	3.0	3.8	4.0	4.1	3.1	4.1	4.6	4.3	4.7	4.5	5.6	7.3	6.9	8.5	8.5	7.7	11.7	5.8
	N	5	19	35	33	17	30	41	24	19	50	50	29	23	35	34	53	42	50	41	46	57	733
Hawaii	%	1.4	14.1	7.9	6.6	0.4	10.0	15.8	7.6	9.5	13.9	11.6	8.4	5.3	9.4	10.5	10.1	17.4	8.0	14.7	13.1	6.7	9.6
	N	4	6	16	5	8	2	1	5	5	5	8	4	5	11	9	17	11	10	10	6	16	164
Idaho	%							4.4	3.6	6.7	3.7			15.6	20.0	10.0	13.7		9.5		13.3		8.8
	N	0	0	0	0	0	0	4	5	4	7	0	0	2	1	5	6	0	4	0	5	0	43
Illinois	%	3.2	5.6	3.3	2.7	2.9	4.0	4.7	4.2	4.1	4.0	4.6	5.2	4.9	6.2	5.4	8.7	7.2	8.6	9.9	9.1	8.4	6.2
	N	10	26	26	24	23	29	29	35	25	49	38	48	61	56	58	87	48	53	60	49	57	891
Indiana	%	0.6	3.6	2.8	3.4	1.9	3.5	3.0	5.2	4.5	3.7	3.8	5.0	6.4	5.1	5.9	6.9	7.3	8.2	7.8	8.4	8.4	5.9
	N	4	21	15	21	9	15	4	13	12	20	49	24	22	34	25	47	40	39	29	33	57	533
Iowa	%		5.1	2.1	4.3			5.9	5.2	2.4	3.8	5.4	5.9	5.9	5.3	5.0	8.9	7.2	6.5	7.3	5.4	11.3	6.1
	N	0	4	5	2	0	0	1	7	7	10	12	20	10	11	16	16	16	9	13	6	10	175
Kansas	%	2.1	2.6	3.1	4.5	3.4	4.3	4.8	5.7	4.7	4.9	7.0	5.4	5.1	5.5	6.2	5.4	7.3	8.2	8.0	6.4	6.8	5.9
	N	5	3	4	1	18	11	18	15	30	34	40	17	31	42	42	26	40	30	17	17	28	469
Kentucky	%	3.9	1.6	4.3	1.9	5.4	3.7	4.9	5.2	5.1	2.8	6.1	3.6	5.2	6.7	5.4	7.1	5.5	7.7	8.9	10.6	7.4	5.9
	N	5	4	8	12	14	17	35	34	15	22	12	14	21	43	25	45	16	35	20	18	16	431
Louisiana	%	3.4	3.6	2.7	4.1		3.2	3.6	2.5	3.6	1.4	3.7	5.7		4.5	3.1	5.7		8.4	6.0	13.8		3.9
	N	1	8	7	3	0	5	6	1	4	1	1	1	0	2	10	3	0	2	1	1	0	57
Maine	%		1.0			3.1	4.9	6.0	3.7		7.4	5.6	6.4			11.9	9.6	10.7	12.4	9.7	12.0	10.3	8.7
	N	0	1	0	0	4	19	5	2	0	2	1	8	0	0	10	3	2	4	12	15	24	112
Maryland	%						4.1	4.8	4.9	4.8	4.3	5.4	5.3	8.2	6.7	7.1	8.5	9.5	10.2	11.2	10.3	11.8	6.7
	N	0	0	0	0	0	21	45	38	36	111	65	24	16	31	21	53	37	28	29	30	12	597
Massachusetts	%	3.2	2.0	1.4	3.4	4.0	4.1	3.3	5.6	5.1	3.9	4.3	8.1	8.1	8.6	7.6	8.2	8.1	9.0	10.0	11.3	13.5	7.2
	N	14	9	7	9	7	12	13	16	18	14	17	14	21	24	18	26	11	24	19	33	19	345
Michigan	%	3.2	2.1	2.7	3.2	4.0	4.3	4.4	6.7	5.9	4.6	4.3	5.8	7.1	7.8	9.3	9.7	8.6	9.2	8.7	9.6	10.3	7
	N	10	9	32	52	76	39	29	49	53	41	89	54	53	61	66	86	76	79	63	81	69	1,167
Minnesota	%	3.4	1.8	3.7	4.5	7.0	4.1	3.0	6.7	5.1	4.2	7.2	7.9	5.7	8.7	8.9	6.3	8.8	8.7	8.3	7.9	14.3	6.9
	N	1	3	7	12	3	14	4	7	8	5	1	5	10	9	6	6	11	13	16	14	7	162
Mississippi	%		5		2.9		3.9	5.3	1.5	2.0	1.3		6.6		4.2	4.8	10.8	4.0	6.8	5.4	6.6	6.3	4.8
	N	0	1	0	2	0	5	2	2	1	3	0	1	0	4	1	1	2	7	2	2	2	38
Missouri	%	3.4	3.2	2.2	3.5	4.6	3.9	4.5	4.7	4.6	3.5	4.9	5.3	5.9	6.3	6.2	6.4	6.8	7.7	10.0	9.8	9.4	6.3
	N	8	13	31	17	21	25	17	23	29	21	40	24	25	57	78	88	42	48	47	53	58	765
Montana	%	2.3		3.7	8.3	4.2	4.7	4.9	4.6		7.8	9.5	7.1	6.1	5.5	8.7	7.4	12.3	12.0	12.0	15.5	15.5	8.8
	N	3	0	7	4	4	1	9	2	0	17	15	40	30	33	42	38	14	49	21	18	9	356
Nebraska	%		7.7	2.5	2.7		3.6			6.6	5.0	4.2	6.7		6.9	5.1	4.8	6.8	6.0	8.5	1.5	7.3	5.7
	N	0	3	3	1	0	1	0	0	1	6	8	3	0	1	5	3	10	7	4	1	6	63
Nevada	%	6.7	1.6	4.2	3.1	4.0	3.2	4.5	4.8	4.4	5.9	3.2	6.3	4.1		14.9	5.4	7.6		16.9	11.7	13.1	6.1
	N	2	6	9	8	19	12	10	13	17	11	4	1	4	0	2	2	1	0	3	7	19	150
New Hampshire	%			2.2					4.4		3.3					8.6	6.6	9.5	13.0	11.9	13.5	11.8	8.7
	N	0	0	8	0	0	0	0	5	0	1	0	0	0	0	2	6	2	1	6	9	7	47
New Jersey	%	2.7	3.3	3.1	3.3	2.1	3.6	5.1	3.2	4.6	6.2	3.4	4.6	4.3	9.3	6.6	6.7	11.9	10.4	9.3	9.6	14.0	7.1
	N	5	1	1	1	11	21	8	3	5	8	4	14	4	10	8	6	6	17	11	10	18	172
New Mexico	%	3.8	3.1	3.1	3.4	4.0	3.9	4.6	4.5	5.6	3.6	4.8	6.1	6.0	5.8	10.9	7.3	8.2	8.8	9.0	10.1	8.1	4.8

	N	2	78	103	117	41	79	56	48	27	39	41	30	47	30	6	41	42	23	16	10	18	894
New York	%	3.3	2.8	2.4	2.7	3.1	4.0	3.5	4.3	4.5	4.7	5.5	7.7	11.5	10.1	10.5	10.9	10.9	11.2	12.3	13.0	14.6	9.1
	N	35	53	94	65	53	73	62	41	50	69	102	113	165	135	151	140	121	117	155	172	211	2,177
North Carolina	%	2.9	1.3	2.8	4.0	4.4	4.3	4.8	4.2	3.6	3.3	4.2	8.7	4.2	3.9	6.3	6.1	8.7	8.0	11.2	8.9	7.2	6.8
	N	2	3	7	3	4	4	5	5	8	8	5	5	1	15	16	22	26	23	18	26	32	238
North Dakota	%			1					4.9		3.1			1.9	13.6	8.7		9.7	15.5	9.7			7.8
	N	0	0	1	0	0	0	0	5	0	3	0	0	1	1	3	0	3	3	2	0	0	22
Ohio	%	4.0	4.2	4.1	4.1	3.2	4.7	4.7	5.0	6.6	4.3	6.3	5.9	6.2	6.7	8.1	8.7	10.1	8.4	8.8	9.3	6.7	6.8
	N	3	9	26	9	10	57	48	26	30	49	62	34	18	63	89	67	36	62	29	53	42	822
Oklahoma	%		3.3	2.2	3.8		2.9	1.6	2.8	2.6	2.2	4.5		4.6	4.7	4.5	4.6	6.7	3.8	5.7	6.0	4.3	3.6
	N	0	8	14	5	0	4	2	2	2	5	3	0	5	6	1	3	2	2	2	2	2	70
Oregon	%	8.1	5.0	2.4	4.2	4.3	4.3	4.8	7.6	6.2	3.5	6.6	7.8	8.3	9.1	9.2	7.2	7.5	11.3	9.9	9.4	11.8	8.4
	N	14	20	10	23	8	7	8	15	14	10	16	4	28	29	28	29	36	78	41	39	45	502
Pennsylvania	%		3.1	2.4	2.0	3.4	4.1	4.3	5.1	5.4	2.9	7.5	4.9	8.1	7.0	8.9	7.9	9.4	7.7	10.1	8.1	12.5	6.5
	N	0	9	21	20	50	27	17	16	25	53	38	44	21	40	43	42	30	39	48	32	26	641
Rhode Island	%	4.4	2.8	0.9	4.6		4.3		6.5	4.5	2.5	1.5	8.4	6.0	6.1	11.8	6.2		10.2	7.7	10.0	13.8	6.5
	N	4	1	5	1	0	6	0	5	3	3	1	3	3	5	6	1	0	4	5	4	1	61
South Carolina	%	2.4	3.3	2.7	4.0	3.8	3.7	5.0	3.4	3.8	4.3	4.1	5.4	3.9	4.6	4.9	6.6	7.0	5.4	6.7	8.7	8.5	4.5
	N	1	12	10	11	6	19	6	9	13	14	17	16	13	8	10	4	9	6	6	4	4	198
South Dakota	%					1.7	1.9		4.2	16.3	5.3	3.9	5.0	4.7	5.1	0.8		4.7	9.2	6.6	3.9	7.6	5.8
	N	0	0	0	0	3	3	0	2	4	2	8	7	3	2	1	0	1	2	7	2	5	52
Tennessee	%	2.4	4.1	3.5	2.9	3.8	4.0	4.0	3.5	3.3	3.3	4.3	4.1	5.7	4.4	5.6	6.6	6.7	8.2	9.2	6.8	10.0	5.9
	N	4	3	11	9	22	11	19	20	43	22	62	13	17	25	27	43	65	36	19	30	77	578
Texas	%	3.5	2.8	3.0	3.3	3.3	3.8	4.3	4.3	4.4	2.8	3.8	4.7	4.7	4.5	5.8	5.0	5.8	6.8	7.7	7.0	6.6	4.1
	N	33	365	519	228	120	359	212	151	137	202	254	233	233	171	74	129	97	97	83	88	87	3,872
Utah	%	4.2	1.5	5.6	3.8	4.8	5.6	4.5	5.1	4.7	5.4	4.8	8.1	7.8	5.2	7.7	7.4	11.2	11.3	8.8	11.5	7.9	7.1
	N	4	2	4	8	8	8	5	6	10	21	19	13	3	9	16	7	15	19	22	6	8	213
Vermont	%	3.1	7.7	3	0.8	6.7		8.9	5.7	2.3	1.9	8.9	8.8	13.3	12.6	15.5	14.8	14.7	13.2	13.3	15.1	13.7	11.8
	N	3	1	5	2	8	0	1	3	4	1	9	13	15	13	15	10	12	13	12	19	11	170
Virginia	%		3.6		6.9		4.0	4.3	4.1	3.9	5.1	5.2	5.6	5.4	6.0	7.8	6.6	7.7	8.7	8.8	9.9	12.5	7.1
	N	0	1	0	1	0	9	20	12	17	24	36	29	34	54	49	37	59	35	45	31	36	529
Washington	%	4.6	5.0	7.5	6.8	7.4	6.9	8.8	8.1	7.1	9.4	11.0	10.8	14.3	14.0	15.8	11.6	11.0	11.4	13.3	13.8	13.8	11.9
	N	10	19	32	19	8	13	14	28	31	43	75	41	92	104	117	137	94	71	82	70	33	1,133
West Virginia	%			1.8			7.9	5.1	5.4	2.4	4.6	5.4	4.6	5.8	6.4	5.0	7.7	10.6	7.6	8.7	10.4	8.2	7.2
	N	0	0	1	0	0	6	2	3	4	15	18	10	3	10	17	11	5	32	17	31	10	195
Wisconsin	%	3.3	1.5	1.9	3.4	3.5	1.3	4.4	2.6		3.2	4.2	6.5	6.3	8.3	5.0	12.5	9.4	6.9	12.1	8.1	11.3	7.3
	N	1	4	8	12	5	1	5	1	0	7	2	4	8	34	27	13	19	8	3	5	30	197
Wyoming	%				5.7	2.7	2.7	5.5	4.8	2.2	4.3	1.5				5.0	4.9	9.0		5.0		20.8	5.1
	N	0	0	0	3	1	4	1	1	1	1	1	0	0	0	17	1	1	0	2	0	1	35
Total	%	3.8	3.3	3.2	3.7	3.8	4.0	4.5	5.0	4.9	4.6	5.4	6.1	7.3	7.2	8.3	8.1	8.8	9.6	10.0	9.9	10.7	6.3
	N	741	1,519	2,452	1,978	2,042	3,742	1,382	1,323	1,307	1,783	1,894	1,665	1,647	1,832	1,858	2,233	2,015	2,080	1,924	1,717	2,023	39,157