NBER WORKING PAPER SERIES

THE EFFECT OF MEDICAL MARIJUANA LAWS ON THE HEALTH AND LABOR SUPPLY OF OLDER ADULTS: EVIDENCE FROM THE HEALTH AND RETIREMENT STUDY

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Working Paper 22688
http://www.nber.org/papers/w22688

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2016, Revised September 2017

Previously circulated as "The Impact of Medical Marijuana Laws on the Labor Supply and Health of Older Adults: Evidence from the Health and Retirement Study." This work was supported by the National Institute on Aging (K01AG041763). Findings do not represent the views of the sponsor. We thank Brady Horn, Ian McCarthy, and seminar participants at McMaster University, Cornell University, the 2016 Midwestern Health Economics Conference, and the 2016 American Society of Health Economists Biennial Conference for helpful comments. We thank Kevin Zhang for excellent research assistance. All errors are our own. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

At least one co-author has disclosed a financial relationship of potential relevance for this research. Further information is available online at http://www.nber.org/papers/w22688.ack

The effect of medical marijuana laws on the health and labor supply of older adults: Evidence from the Health and Retirement Study

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NBER Working Paper No. 22688
September 2016, Revised September 2017
JEL No. I10,I18,J20

ABSTRACT

We study the effect of state medical marijuana laws on older adult health and labor supply. Older adults have the highest rates of many health conditions for which marijuana may be effective in alleviating work-impeding symptoms, implying that this population is more likely experience health and labor supply benefits from access to marijuana than younger populations. We use the Health and Retirement Study to study these questions and estimate differences-in-differences regression models. Three principle findings emerge from our analysis. First, we document that medical marijuana law passage leads to reductions in chronic pain and improvements in self-assessed health among older adults. Second, we show that passage of a state medical marijuana law leads to increases in older adult labor supply, with effects concentrated on the intensive margin. Third, effects are larger among older adults with a health condition that would qualify for medical marijuana use under state laws. Observed health improvements may allow older workers to increase their participation in the labor market.

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1 Introduction

Legalization of marijuana, for medicinal or recreational use, is highly controversial in the United States. As of 2017, 29 U.S states and the District of Columbia (DC) have passed laws legalizing use of marijuana for medical purposes ('MMLs').[1] Critics argue that any legalization of marijuana will increase marijuana addiction, misuse of related substances, crime, traffic accidents, and healthcare costs. Advocates on the other hand highlight the potential health benefits of medical marijuana, which can include improving the symptom burden associated with pain and number of other health conditions. Given this tension, policymakers must have a solid evidence base on both the potential costs and benefits of expanded access as they determine how best to regulate marijuana. To date, the majority of economics studies examining the effects of state MMLs have focused on intended and unintended consequences of these policy changes among youth and working age adults.

In this paper, we examine the effects of MML passage on older adult health and labor supply. Older adults adults have worse health than younger adults, including higher prevalence of many of the health conditions whose symptoms can be effectively treated with medical marijuana (Gordon et al., 2002; Morgan, 2003; Leske et al., 2008; Unruh et al., 2008; Nahin, 2015). In 2015, 29% of the overall adult population reported lower back pain, 35% of adults age 45 years and older reported this condition. In addition, while 22.7% of all adults suffer from arthritis, the prevalence of this condition is 29.3% among adults 45 to 64 years and 49.6% among adults 65 years and older (Barbour, 2017). Given typical age patterns of disease incidence, if medical marijuana access leads to improved symptom control, the benefits of MML passage may be concentrated among older adults. However, older adults are understudied in current clinical medical marijuana research (Ahmed, Elsen, Marck, Rikkert, & Marcel, 2014; Yi, 2015).

Poor health is frequently cited as a reason for older adult labor force exit (Dwyer & Mitchell, 1999; McGarry, 2004; Case & Deaton, 2005; Kamaleri, Natvig, Ihlebaek, & Bruusgaard, 2009; Miranda et al., 2010; Datta Gupta & Larsen, 2010; Garthwaite, 2012; Saastamoinen et al., 2012; Kaila-Kangas et al., 2014). The U.S. population is aging and older adults currently represent a large share of the population, and this share is expected to increase substantially over time. For example, in 2012 there were 43.1M adults 65 years and older (13.7% of the population) and this number is projected to rise to 83.7M (20.9%

[1] Although not the focus of our analysis, at the time of writing seven states (Alaska, California, Colorado, Maine, Massachusetts, Nevada, Oregon, and Washington) and DC have legalized marijuana for recreational purposes.

of the population) by 2050 (Ortman, Velkoff, Hogan, et al., 2014). If access to marijuana for medical purposes through passage of an MML reduces symptoms associated with work-impeding health conditions, this access could lead to enhanced participation in the labor market within the fastest growing segment of the population.

A clear understanding of MML effects is timely as the Trump Administration and Republican Congress have proposed allowing the Rohrabacher-Farr Amendment (2014) to expire.[2] This Amendment prohibits the federal Department of Justice from spending federal funds to enforce federal anti-marijuana laws within states that have implemented an MML.[3] Policymakers must have solid evidence on the potential implications of re-shaping the future of federal oversight of state laws related to marijuana used for medical purposes. Moreover, state policymakers in the 21 states that have not passed an MML may value additional information on the full effects of MMLs on health and other important social outcomes to help decide if legalizing medical marijuana would benefit their constituents.

The objective of this paper is to provide the new empirical evidence on the effect of state MML passage on older adult health and labor supply. Specifically, we test the effect of MML laws on several health outcomes (pain, work-limiting health conditions, self-assessed health, and depression), and measures of labor supply along both the extensive and intensive margins. While no large-scale national surveys collect medical marijuana usage as well as our outcomes of interest, we are able to study the extent that our results are concentrated among patients with one or more health conditions that would typically qualify a patient for medical marijuana use in legalizing states (Sabia, Swigert, & Young, 2017; Bradford & Bradford, 2016). We use data drawn from the Health and Retirement Study (HRS) between 1992 and 2012 to estimate differences-in-differences regression models that control for a wide range of state-level characteristics that may predict our outcomes and the propensity of a state to pass an MML, and state-specific trends. The HRS, which is a longitudinal survey specifically designed to track both health and labor market experiences of older Americans, is particularly well-suited to our study objectives.

Our analysis of health outcomes suggests that passage of an MML leads to reductions in chronic pain and improved self-assessed health among older adults. For example, post-MML the probability of assessing one's health as very good or excellent increases by 3%.

[2]See, for example, http://thehill.com/policy/finance/332182-trump-pushes-back-against-ban-on-state-medical-marijuana-interference and https://www.thenation.com/article/how-congress-could-give-trump-the-green-light-to-go-after-medical-marijuana/ (accessed May 6th, 2017).

[3]The Amendment must be renewed each fiscal year to remain in effect, thus federal oversight of state MMLs is likely to continue for the duration of the Trump Administration.

Our findings further suggest that passage of an MML leads to an increase in the probability of full-time employment by 3% and weekly hours worked (conditional on working) by 3%. Because we do not find evidence that passage of an MML changes the probability of any work, we interpret our findings to imply that passage of an MML allows currently working older adults to increase their participation in the labor market rather than motivating a return to paid employment for those older adults who have previously left the labor market due to health conditions. We hypothesize that the observed health improvements may drive the labor supply effects. Overall, we find that MML effects, both for health and labor supply, are concentrated among older adults likely to use marijuana for medical purposes based on their health histories.

This paper is organized as follows: Section 2 provides background on MMLs and marijuana use among older adults, and a review of the related literature. Section 3 provides a discussion of mechanisms through which MMLs may influence both health and labor supply. Data, variables, and methods are presented in Section 4. Section 5 discusses our main results. Robustness checks are reported in Section 6. Finally, Section 7 provides a discussion and potential policy implications.

2 Background and related literature

2.1 Marijuana regulation in the U.S.

Marijuana is a controlled substance under U.S. federal law, thus its possession and distribution are illegal. The Controlled Substances Act of 1970 classifies marijuana as a Schedule I drug. Schedule I is the strictest drug classification in the U.S. and is reserved for 'Drugs with no currently accepted medical use and a high potential for abuse.' Moreover, 'Schedule I drugs are the most dangerous of all the drug schedules with potentially severe psychological or physical dependence.' Schedule I drugs include ecstasy, heroin, and lysergic acid diethylamide (LSD). For comparison, cocaine is a Schedule II drug, Valium is a Schedule IV drug, and Robitussin cough syrup is a Schedule V drug.

Schedule I status severely limits researchers' capacity to utilize marijuana for clinical trials. This barrier has lead to a small set of U.S.-based marijuana clinical trails (Williams, Olfson, Kim, Martins, & Kleber, 2016; Stith & Vigil, 2016). In addition, clinical trials are only permitted to test low potency tetrahydrocannabinol (THC)[4] marijuana, which is

[4]THC is the principle psychoactive compound of marijuana.

markedly weaker than the medical marijuana available to patients through home cultivation or dispensaries, raising questions regarding the extent to which clinical trial findings generalize to actual patients' experiences (Stith & Vigil, 2016).

As of 2017, 29 states and DC have implemented an MML. To legally access marijuana, patients must receive a recommendation from a medical doctor indicating their need for this medication and provide evidence of legal residence within the state. State laws differ in terms of the conditions that qualify patients for medical marijuana. Common qualifying conditions are cachexia, cancer, digestive conditions, epilepsy, HIV/AIDS, glaucoma, muscle spasms, multiple sclerosis, and pain (Bradford & Bradford, 2017; Sabia et al., 2017). Based on surveys of actual patients, pain appears to be the most common condition leading to use, e.g., Reinarman, Nunberg, Lanthier, and Heddleston (2011) and Nunberg, Kilmer, Pacula, and Burgdorf (2011).

Table 1 outlines the MML effective date for each state that has passed an MML through 2017 (Sabia & Nguyen, 2016). The first state to pass an MML was California in 1996. This law removed criminal penalties for marijuana possession, cultivation, and use for a set of health conditions. Other early adopting states include Oregon (1998), Washington (1999), Alaska (1999), and Maine (1999). Florida and West Virginia are the most recent states to pass an MML (2017). These state law changes provide identification of MML effects in our empirical models (discussed later).

In our analyses we focus on the effect of any MML on older adult outcomes. However, there is substantial heterogeneity in these state laws. For example, in terms of access to marijuana, some states permit patients to obtain marijuana through private cultivation (e.g., at home or in collective gardens) while other states allow patients to obtain the product from state-licensed dispensaries. We capture the average effects of implementing an MML. This effect may reflect, among other things, public perceptions of marijuana as a new medical treatment option or risk of using marijuana recreationally, legal access to medical marijuana, and easier access to, and lower prices for, recreational marijuana.[5]

[5]In previous versions of this manuscript our analysis included more of an emphasis on legal access through home cultivation and dispensaries, now noted as a robustness check. We implemented this change due to controversy surrounding the correct legal coding for several states (in particular opening dates for dispensaries) and to make our results more comparable to other economics papers in the MML literature. More details are available on request.

2.2 Medical marijuana use among older adults

Medical marijuana offers older adults a new treatment option for patients suffering from a number of health conditions. Although clinical evidence is limited, randomized control trials have found that medical marijuana is an effective treatment for symptoms associated with pain, anxiety, depression, nausea, psychosis, sleep disorders, and spasticity (Sallan, Cronin, Zelen, & Zinberg, 1980; Joy, Watson, & Benson, 1999; Lynch & Campbell, 2011; Hill, 2015; Whiting et al., 2015).[6] Further, recent neuroscience research on mice shows that that marijuana can improve brain function among older mice, with marijuana compounds potentially acting as anti-aging molecules in the brain (Bilkei-Gorzo et al., 2017).[7] The most commonly cited health conditions among patients seeking medical marijuana include pain, mental health problems, nausea, and sleep disorders, and the majority of medical marijuana patients report that medical marijuana is more effective than their previous treatment (Nunberg et al., 2011; Troutt & DiDonato, 2015).

Because the HRS data will not allow us to study marijuana use among older adults, we review the available evidence to assess use of this product among older adults. Although states do not release individual-level data, our analysis of available data suggests that 20% to 60% of all registered medical marijuana users in U.S. states reporting demographic information are over age 50.[8] Recent studies of medical users registering in their state (Anderson, Hansen, & Rees, 2013; Yi, 2015; Fairman, 2016; Kaskie, Ayyagari, Milavetz, Shane, & Arora, 2017) and convenience samples of medical marijuana patients (Nunberg et al., 2011; Reinarman et al., 2011; Ilgen et al., 2013) also suggest that older adults represent a substantial share of medical marijuana patients.[9] States that include a larger number of impairments disproportionately experienced by older adults as qualifying conditions have greater participation by older adults in medical marijuana use than other states (Kaskie et al., 2017).

Based on survey data from the National Survey of Drug Use and Health (NSDUH), a dataset used by the federal government to monitor substance use within the U.S., 6.1% of adults ages 55 to 64 years and 1.3% of adults age 65 years and older reported any form of marijuana use in the past month in 2014, reflecting a 455% and 333% increase since 2002

[6] Marijuana's Schedule 1 classification severely limits researchers to use marijuana in clinical trials.

[7] However, marijuana reduces brain function among younger mice.

[8] Authors' calculation using data from eleven states (Alaska, Arizona, California, Colorado, Delaware, Hawaii, Illinois, Minnesota, Montana, Nevada, and Oregon) that, at the time of writing, require patients to register with the state to legally use medical marijuana and publicly report patient demographics.

[9] There are differences across studies, which is not unexpected given that these studies rely on very small samples of individuals seeking medical marijuana in select locations.

respectively (Azofeifa, 2016).[10] Antecdotal evidence suggests that medical marijuana sellers are marketing their products towards older adults.[11]

Finally, as noted by Sabia and Nguyen (2016), younger populations are less likely to use marijuana available through MMLs for medical purposes and are more likely to use this product for recreational purposes. Collectively, these statistics provide evidence that a non-trivial share of older adult marijuana users are using marijuana medically.

2.3 Economic analyses of state medical marijuana laws

A growing economic literature explores the effect of MMLs on a range of outcomes. We next provide a brief review of the studies most relevant to our work. We place particular emphasis on estimates for our study population: older adults.

Several studies investigate the extent to which MML passage changes marijuana use among adults.[12] In two studies that leverage data on arrests and admissions to substance use disorder (SUD) treatment, Chu shows that passage of an MML leads to a 10% to 20% increase in arrests for marijuana-related possession and SUD admissions within the general popualation (Chu, 2014, 2015). Effects of MMLs on older adult marijauna-related arrests, defined by Chu (2014) as those 45 years and above, range from 1.1% to 11.9% and are often statistically indistinguishable from zero. Using NSDUH, Wen et al. (2015) show that among adults 21 years and older passage of an MML leads to a 14% (15%) increase in prior month marijuana consumption (near daily use). The authors note that because the share of medical marijuana users is low, the estimated increases likely reflect some spillover effects from medical to recreational use (Wen et al., 2015). Choi (2014), also using NSDUH, finds a similar relationship between MMLs and marijuana use among those 21 years and older.[13]

[10] In 2002, 1.1% of 55 to 64 year olds reported using marijuana and 0.3% of those 65 years and older reported using marijuana in the past month. For comparison, the overall past month use rate among those 12 years and older was 8.4% in 2014, up from 6.2% in 2002, leading to a 35% increase (Azofeifa, 2016).

[11] https://seniordirectory.com/articles/info/10-things-seniors-should-know-about-medical-marijuana; https://www.northshire.com/book/9781579512422; https://mjbizmagazine.com/serving-the-senior-demographic/; and http://www.weedsthatplease.com/Seniors/index.htm (accessed June 8th, 2017).

[12] Several economic studies estimate the effect of MML passage on marijuana use among adolescents and young adults (Anderson, Hansen, & Rees, 2015; Pacula, Powell, Heaton, & Sevigny, 2015; Wen, Hockenberry, & Cummings, 2015). For brevity, we omit a discussion of these studies, apart from noting that, based on our reading of the literature, the extent to which MML passage influences adolescent and young adult marijuana use is unclear at this time.

[13] The effects of MML passage may also extend to the use of other substances. For instance, Anderson et al. (2013) show that, following passage of an MML, fatal traffic accidents decline 8% to 11%, with larger effects for accidents that do not involve alcohol, suggesting that marijuana and alcohol are substitutes. In an extension to the main analyses, the authors estimate separate regressions by age group, findings for older adults (50 to 59 years, and 60 years and older) are generally smaller in magnitude and imprecise. The

Increases in the number of marijuana users may also change both the price and the characteristics of the product available in the illegal drug market. For instance, Anderson et al. (2013) document that the price of high quality street marijuana declines by 9.8% to 26.2% decline following passage of an MML. Sevigny, Pacula, and Heaton (2014) provide suggestive evidence that the potency of marijuana samples seized by law enforcement agents increases following MML passage. Post-MML potency increases by a half a percentage point, although the estimate is not precise.[14]

There is also evidence that MML passage leads to changes in health outcomes. Sabia et al. (2017) find that passage of an MML leads to a 2% to 6% decline in the probability of obesity, with comparable findings for older adults (defined as 50 years and older). In an examination of potential mechanisms for the the MML-obesity relationship, the authors show that, following passage of an MML, days in poor physical and mental health decline while physical activity increases although the effects are sensitive to the inclusion of state trends. Findings for older adults are broadly comparable to the full sample, but are generally imprecise in models that include state trends. Anderson, Rees, and Sabia (2014) document that MML passage leads to a decline in completed suicides among men aged 20 to 29 and 30 to 39, but not other demographic groups. Finally, Abouk and Adams (2017) show that, post-MML, cardiovascular deaths increase by 2.3% among men and 1.2% among women. Effect sizes are even larger among older adults (defined as adults 65 years and older).

Germane our study, evidence suggests that patients are in fact using marijuana medically to treat symptoms associated with a range of health conditions following passage of an MML. While currently available survey data does not, to the best of our knowledge, allow researchers to separately examine medical and recreational marijuana use, insight can be gleaned from medication prescribing patterns. Two recent studies take this indirect, but nonetheless informative, approach. Bradford and Bradford (2016) analyze prescribing pat-

authors, leveraging survey data, show that several measures of alcohol use decline post-MML among adults and adults 50-59 years, but estimates are impresise for adults 60 years and older. Subsequent analyses offer mixed evidence on the effect of MML passage on alcohol use, however. Wen et al. (2015) find that measures of alcohol misuse *increase* post-MML while Sabia et al. (2017) document that alcohol misuse *decreases*. Chu (2015) explores the effect of MML passage on the use of cocaine and heroin. Post-MML drug possession arrests and admissions to SUD treatment related to these substances may decline, although the effects vary often close to zero and appear to be sensitive to the empirical specification. Choi, Dave, and Sabia (2016) show that tobacco use declines following passage of an MML. For example, post-MML tobacco consumption declines by 0.3 to 0.7 percentage points. The authors note that these findings are sensitive to the inclusion of state-specific trends, however. Findings are larger in magnitude for older adults; defined by the authors as adults 55 years and older.

[14]The authors document somewhat stronger evidence in analysis of heterogeneity in MML attributes.

terns among Medicare patients (a population similar to our analysis sample of older adults).[15] The authors document declines in prescriptions for therapeutic substitutes after passage of an MML that allows legal access for a number of conditions including pain, anxiety, depression, nausea, psychosis, seizures, and sleep disorders. The magnitude of the prescription declines is non-trivial. For example, 5.7% for pain medications, 5.0% for anxiety medications, 5.4% for nausea medications, and 4.5% for psychosis medications. In a follow up study, Bradford and Bradford (2017) document similar substitution patterns across medications following passage of MML passage within the Medicaid population.[16]

Relatedly, two studies suggest that passage of an MML leads to a reduction in opioid use, opioids are used to treat chronic pain and thus are plausibly theraputic substitutes for marijuana. Bachhuber, Saloner, Cunningham, and Barry (2014) use mortality data to show that passage of an MML reduces the opioid overdose rate by 24.8%. Similarly, Powell, Pacula, and Jacobson (2015) document that MML passage reduces admissions to SUD treatment for opioid use and overdose deaths attributable to opioids.[17] Collectively, these findings suggest that (i) some individuals, in paritcular older individuals, are using marijauna medicaly post-MML and (ii) passage of an MML leads to substitution towards medical marijuana and away from more conventional treatment options.

To the best of our knowledge, only two studies explore the effect of MML implementation on labor market outcomes. (i) Sabia and Nguyen (2016) leverage data from the Current Population Survey (CPS) and document that passage of an MML may decrease wages by 3% among younger males, but passage is largely unrelated to measures of considered labor supply (any work and conditional hours worked). In particular, the authors do not find evidence that passage of an MML affects these measures among individuals ages 50 to 64 years. (ii) Ullman (2016), also using CPS data, shows that passage of and MML reduces work absences by 8.4% to 8.7%, although MML effects are somewhat sensitive to alternative specifications for older workers.

3 Mechanisms

We next discuss how expanded access to marijuana through the passage of an MML may influence first health and second labor supply among older adults.

[15] Medicare is a public insurance program that finances healthcare services for older adults.

[16] Medicaid is a public insurance program that finances healthcare services to the poor.

[17] The authors find evidence that the MML must allow legal access to medical marijuana to influence the opioid-related outcomes they examine.

3.1 Health

Medical marijuana offers a new treatment option for patients suffering from a number of health conditions. While marijuana may not improve health *per se*, use of this medication may reduce symptoms associated with a range of health conditions. As noted in the previous section, there is evidence that patients may substitute medical marijuana for other conventional treatments (Bachhuber et al., 2014; Powell et al., 2015; Bradford & Bradford, 2016, 2017). However, the extent to which such medication substitution affects patient health outcomes is *ex ante* ambiguous. A complicating factor in predicting the health effects of MML passage is that medication – be it marijuana or any other medication – effectiveness simply varies across patients (Porter, 2010).

Patient health and symptom burden should improve if medical marijuana is more effective than a patient's previous treatment program (which may include no treatment) and/or has a less aggressive side effect profile, and worsen if marijuana is a less effective treatment. If MML passage primarily leads to increases in recreational use (Wen et al., 2015), then we expect no improvement, and perhaps a decline, in health for the new recreational users.

Even if marijuana is more effective than a patient's previous treatment, switching to medical marijuana may also have adverse patient health effects if this substitution induces patients to terminate treatments addressing a broader set of symptoms. For instance, the treatment of chronic pain is often characterized by utilization of both prescription medications designed specifically to minimize pain symptoms and anti-depressants (Sansone & Sansone, 2008). Healthcare providers prescribe these medications in combination because some anti-depressants directly act on a different set of pain receptors than typical pain relievers, and because depression and pain can co-occur. Patients who opt to use medical marijuana (which is generally obtained outside the conventional healthcare system) may lose access to valuable secondary treatments. Moreover, regular interactions with healthcare providers, who may be better able to address changes in health than patients themselves, may also decline as patients withdraw from conventional healthcare.

3.2 Labor supply

Older adults may increase labor supply following medical marijuana access if the new treatment more effectively alleviates symptoms or provides similar efficacy with fewer side effects. Conventional prescription medications for many medical marijuana-qualifying health conditions often present patients with non-trivial side effects that likely impede the ability to

work. Anti-anxiety medications side effects include addiction, confusion, headaches, irritability, trouble concentrating, and worsening of depressive symptoms (Longo & Johnson, 2000; Stewart, Ricci, Chee, Morganstein, & Lipton, 2003). Patients using opioid pain relievers often suffer from cardiovascular problems, central nervous system complications, constipation, impaired judgment, itching, nausea or vomiting, and respiratory problems (Szarvas, Harmon, & Murphy, 2003; Swegle & Logemann, 2006; Chau, Walker, Pai, & Cho, 2008).

However, marijuana is a drug that can have intoxicating effects on the user and that has serious side effects including addiction, amotivational syndrome, anxiety, depression, inattention, increased heart rate, lethargy, memory problems, and respiratory problems (Van Ours & Williams, 2011, 2012; Hill, 2015; Volkow et al., 2016). These attributes likely impede health and reduce labor supply, even among adults who use marijuana for medical purposes. If older adults increase recreational marijuana use in response to easier access or perceived safety following MML passage, we expect labor supply to remain unchanged or decline. Labor supply could also decline if use of medical marijuana improves health and the increased value of leisure time decreases the desire to work and, for example, prompts older adults to enter retirement (full or partial).

3.3 Mechanism summary

In sum, there are various, and often off-setting, pathways through which access to marijuana through passage of an MML may effect both the health and labor supply of older adults. These pathways are tightly linked to the ways in which older adults use marijuana obtained through passage of an MML and heterogeneity across individuals in terms of marijuana effects (both medical and recreational use) on these outcomes.

Developing clear predictions for MML effects is hampered by the limited clinical and economic literature on older adults. Indeed, medical scholars note the failure of clinical trials to include older adults and the unique features of older adults that call for separate study (Ahmed et al., 2014; Yi, 2015; Kaskie et al., 2017). Our objective is to provide empirical evidence on the net effects of MML passage within this demographic group. This information is highly relevant to government decision makers as the MML, not other features of marijuana use, is the available policy lever.

4 Data, variables, and methods

4.1 Health and Retirement Study

We draw data from the Health and Retirement Study (HRS) between the 1992 and 2012 interview waves.[18] The HRS is a nationally representative panel survey of Americans over 50 and their spouses administered biennially since 1992. The survey is designed to track health and labor market outcomes among older adults, and is therefore well-suited to our study objectives. Through the 2012 wave, the HRS includes 247,233 interviews with 38,008 older persons. After excluding respondents based on residence outside the U.S., missing state, or proxy response, our analysis sample includes 183,032 respondent/year observations. A limitation of the HRS, similar to all major surveys of older adults of which we are aware, is that it does not collect information on marijuana use, either for medical or recreational purposes. Therefore, our results have a an intent-to-treat (ITT) interpretation.

4.2 State-level medical marijuana laws

Our source for MML effective dates is Sabia and Nguyen (2016).[19] We match the MML effective dates to the HRS on month and year. We construct an indicator variable coded one if a state has an MML in place and zero otherwise. Table 1 reports each state that has passed an MML and the effective dates.

4.3 Outcome variables

The objective of our study is to estimate the effect of expanded access to marijuana for medical purposes through MMLs on health and labor supply outcomes among older adults.[20] We examine four health outcomes which have at least modest evidence supporting the use of medical marijuana as an effective treatment option, are measured in the HRS, and have a plausible link to labor supply. Specifically, we consider measures of (i) chronic pain (any), (ii) depressive symptoms (a count of the number of depressive symptoms as measured by an

[18] Our study period extends through early 2013 when the last of the 2012 wave interviews are collected.

[19] The authors carefully collected effective dates from a range of sources. We refer readers to this paper for more details on the laws and sources.

[20] We acknowledge that recreational marijuana use is also a possible pathway through which MMLs may influence older adult labor supply, but we cannot examine this outcome in our study. Instead we simply note that this relationship, at least among the general adult population, has been established (Anderson et al., 2013; Chu, 2014; Wen et al., 2015) and encourage more research on older adult marijuana use, both for recreational and medical use, by other scholars.

abbreviated eight question version of the Center for Epidemiologic Studies - Depression Scale [CES-D] used in the HRS), (iii) health limiting the ability to work, and (iv) self-assessed health ('SAH', we construct an indicator for reporting very good or excellent health). Our measures of pain and depression are well supported by the clinical literature on marijuana, the measure of health limiting ability to work likely captures a broad set of conditions that could impact one's ability to participate in the labor market, and SAH provides an overall assessment of one's health.

These HRS survey items mirror questions that healthcare providers would use to diagnose and treat conditions such as pain and depression; conditions that are are subjective by nature (National Institutes of Health, 2011). Self-assessed health has been shown to predict, even after conditioning on observable characteristics, more objective measures of health status such as mortality and healthcare utilization (Miilunpalo, Vuori, Oja, Pasanen, & Urponen, 1997; Benjamins, Hummer, Eberstein, & Nam, 2004; Nielsen, 2016). This measure is believed to capture aspects of mental and physical health (Apouey & Clark, 2015). The CES-D measures of depressive symptomatology have been validated in numerous settings (Radloff, 1977; Turvey, Wallace, & Herzog, 1999). These measures are frequently used in the economics literature (Tian, Robinson, & Sturm, 2005; Kapteyn, Smith, & Van Soest, 2008; Atlas & Skinner, 2009; Apouey & Clark, 2015; Maclean, 2013; McInerney, Mellor, & Nicholas, 2013; Maclean, Webber, French, & Ettner, 2015; Horn, Maclean, & Strain, 2017).

We examine three measures of labor supply: (i) any work in the past year (0/1), (ii) whether currently working full-time (0/1), working 35 or more hours per week for at least 36 weeks of the year), and (iii) usual hours worked per week among those who report any work. We take the logarithm of usual hours worked, thus coefficient estimates have the interpretation of an approximation of the percent change.

4.4 Control variables

We control for respondent age, race, Hispanic ethnicity, and education in all regressions.[21] We also include several state-level variables to account for time-varying between-state differences that may be correlated with both the passage of an MML and our outcomes, and hence minimize bias due to omitted variables. To this end, we include an indicator for whether a

[21] To preserve sample size we assign an indicator variable for observations with missing personal characteristics and assign that observation the mean (modal) value for continuous (binary) variables. Results, available on request from the corresponding author, are not appreciably different if we instead exclude observations with missing personal characteristics from the analysis sample or exclude the personal characteristic variables from the regression models.

state has decriminalized marijuana (Pacula, Chriqui, & King, 2003),[22] the beer tax per gallon from the Brewers' Almanac, the unemployment rate among adults 50 years and older from the Current Population Survey Outgoing Rotation Group (CPS-ORG), and hourly wages among adults 50 years and older from the CPS-ORG.[23] We also control for a set of labor market and social policies: effective minimum wage (i.e., the higher value of the state or federal wage), state Earned Income Tax (EITC) as a proportion of the Federal EITC, and maximum food stamp benefit for a family of four from the University of Kentucky Poverty Research Center. Finally, we control for the Governor's political affiliation (Democrat or not).[24] We inflate all nominal values to 2012 terms using the Consumer Price Index - Urban Consumers.

4.5 Empirical model

We estimate the following regression model:

$$Y_{ist} = \alpha_0 + \alpha_1 M_{st} + X_{ist}^{'}\alpha_2 + \tau_{st}^{'}\alpha_3 + \delta_s + \gamma_t + \Omega_{st} + \epsilon_{ist} \quad (1)$$

Y_{ist} is a labor supply or health outcome for older adult i in state s in year t. M_{st} is an indicator for an MML in state s in year t. X_{ist} is a vector of individual characteristics and τ_{st} is a vector of time-varying state characteristics. δ_s is a vector of state fixed effects which capture unobservable (to the econometrician) and fixed factors for each state, and γ_t is a vector of interview wave dummy variables which capture factors that affect the national as a whole. Ω_{st} is a vector of state-specific linear wave trends (that is we interact each state fixed effect with a separate linear wave trend that takes on a value of 1 in 1992, 2 in 1994, and so forth). These trends capture unobservable (again to the econometrician) time-varying factors in an, albeit, linear manner. ϵ_{ist} is the error term. We utilize linear probability models (LPMs) for binary outcomes and least squares for continuous outcomes. We cluster the standard errors around the state (Bertrand, Duflo, & Mullainathan, 2004). All results are unweighted.

Although the HRS does not include information on medical marijuana use, the survey does include questions that reflect whether respondents have many of the underlying symp-

[22]We thank Rosalie Pacula for sharing an updated version of the marijuana decriminalization variable coding scheme.

[23]CPS-ORG data obtained from CEPR (http://ceprdata.org/cps-uniform-data-extracts/cps-outgoing-rotation-group/cps-org-data/; accessed August 1st, 2017). The authors used these data to construct hourly wage and unemployment rate variables. Details available on request from the corresponding author.

[24]We treat the mayor of DC as the *de facto* mayor of this locality.

toms and health conditions that would qualify them for legal access to medical marijuana within states that have passed an MML. We construct an indicator of whether a respondent appears to qualify for medical marijuana if they report (i) current cancer treatment, (ii) current glaucoma, (iii) current arthritis, and / or (iv) current or previous severe pain.[25] We refer to respondents who meet one or more of these conditions as the 'qualifying' sample, which includes 101,112 observations (or 55% of the full sample). While this definition likely captures many potential medical marijuana users, it fails to identify those respondents with diagnoses such as multiple sclerosis, HIV/AIDS, and epilepsy, which are not measured in the HRS. We estimate all specifications of Equation 1 in the full sample and the qualifying sample. We expect that the relationships between MMLs and our outcome variables will be stronger in the qualifying sample than the full sample if MMLs increases access to medical marijuana among patients who benefit from its clinical use. To the best of our knowledge, the HRS is the only large scale survey of older adults that includes sufficient information to identify the population most likely to benefit from access to medical marijuana, and assess whether health and labor supply change in response to this access.

5 Results

5.1 Summary statistics

Table 2 reports summary statistics. In the full sample, 31% report experiencing pain, 29% report that health limits work ability, and 41% report their health as exellent or very good, and the mean number of depressive symptoms is 1.6 (out of a maximum of 8 symptoms). The qualifying sample, as expected, appears to have worse health than the full sample: 43% reports experiencing pain, 39% reports that health limits the ability to work, and 32% reports very good or excellent health, and the mean number of depressive symptoms is 1.8. Turning to labor supply, in the full (qualifying) sample 39% (31%) reports working and 26% (19%) reports working full time, while the mean hours worked per week conditional on any work is 36.7 (34.8). 13% of the full sample and 15% of the qualifying sample reside in a state with an MML. The individual characteristics are comparable to an older sample and the state-level characteristics reflect the national as a whole.

[25]Specifically, if the respondent reported severe pain in any round of the HRS.

5.2 Regression analysis of health outcomes

We first explore the effect of MML passage on older adult health. Results are reported in Table 3. Overall, we find that the health effects of MML passage are concentrated in pain and SAH, we find no statistically significant evidence that MMLs are linked with either the probability of reporting that health limits the ability to work or depressive symptomology. We find that the health effects are more substantial in the qualifying sample than in the full sample. We interpret the more substantial (in terms of magnitude) effects in the qualifying sample to imply that marijuana obtained following an MML is used medically by a non-trivial share of respondents in this sample. More specifically, passage of an MML leads to a 0.2 percentage point (0.6%) reduction in chronic pain and a 1.4 percentage point (3.4%) increase in the probability of reporting very good or excellent SAH; although the MML estimate in the pain regression is imprecise. Within the qualifying sample we find that passage of an MML leads to a 2.2 percentage point (5.1%) reduction in reporting pain and a 2.5 percentage point (7.8%) increase in the probability of reporting very good or excellent health.

The null findings for health limiting work are somewhat surprising. However, this question does not probe the particular aspect of health that limits the respondent's ability to work. While our data will not allow us to explore this somewhat surprising finding, we hypothesize that the set of health conditions that respondents have in mind when responding to this question may include conditions for which we would not expect marijuana to be effective in addressing symptoms (e.g., blindness, blood pressure, deafness, heart conditions, stroke). Another possibility is that marijuana treats symptoms associated with health conditions, but does not treat the underlying health conditions *per se*. Taken in this context, although older adults may continue to report that they have a health condition that limits their ability to work post-MML, they may experience less burdensome symptoms associated with the condition through the use of medical marijuana.

Our finding that depressive symptoms are unchanged following passage of an MML is line with Anderson et al. (2014) who show that MML passage does not lead to reductions in completed suicides (which we acknowledge likely capture a much more serve measure of mental health problems) within the general population, although it departs somewhat from the finding of Sabia et al. (2017).[26]

[26]However, Sabia et al. (2017) show that including state-specific trends – we include state-specific linear time trends in our regressions – weakens the observed relationship. Thus, the correspondence between our findings and the findings of Sabia et al. (2017) varies across specifications.

5.3 Regression analysis of labor supply outcomes

Table 4 reports results on the effect of MML passage on older adult labor supply. We find no statistically significant evidence that MML passage leads to changes on the extensive margin of labor supply: the coefficient estimates, in both the full sample and the qualifying sample, in the any employment regressions are small in magnitude and imprecise. We interpret this finding to suggest that MML passage does not draw older workers into the labor market (or, perhaps more accurately, allow older workers to re-enter the labor market). We next consider the effect of MML passage on the intensive margin of labor supply: full time work propensity and conditional hours worked per week. We observe that passage of an MML leads to increases in labor supply along both of these measures. More specifically, passage of a MML leads to a 0.8 percentage point (3.1%) increase in the probability of fulltime work and a 3.3% increase in hours worked per week in the full sample.[27]

The magnitude of the MML effects are more substantial within the qualifying sample: passage of an MML leads to a 1.1 percentage point (5.8%) increase in the probability of working fulltime and a 6% increase in weekly hours worked (conditional on any work). While we lack data on marijuana use, recreational or medical, the combination of our health and labor supply effects suggest that, on average, improved capacity to work dominates any work-impeding effects of marijuana use. In particular, we hypothesize that reductions in symptoms associated with chronic health conditions (e.g., pain) and overall well-being, as measured by SAH, allow older adult workers to increase the amount of time they allocate to paid employment post-MML.

6 Robustness checks

We next review several robustness checks that we conducted to assess the stability of our findings.

[27] In line with the null findings for any employment, including those respondents who do not report any work leads to a small positive, but imprecise, coefficient estimate. We interpret these null findings generated in the unconditional sample as further evidence that labor supply effects are driven by changes on the intensive margin. Moreover, because we do not observe MML effects on the extensive margin, we believe that our conditional hours worked findings are not likely driven by conditional-on-positive bias (Angrist & Pischke, 2009).

6.1 Parallel trends

The principle assumption underlying DD models is that the treatment (states that pass an MML) and comparison (states that do not pass an MML) would have trended similarly had the treatment group not been treated (i.e., the 'parallel trends' assumption). This assumption, while necessary for DD models to recover causal effects, is inherently untestable as the treatment group was in fact treated and therefore the counterfactual is not observed.

We attempt to provide suggestive evidence that our HRS data is able to satisfy this assumption. To verify that states had similar trends in health and labor supply outcomes prior to law passage, we use pre-period data to estimate regression models similar to Equation 1 with the exception that we replace the MML variable with an interaction between the treatment group (states that pass MML) and a linear time trend. The regression model we use to test parallel trends is as follows:

$$Y_{ist} = \beta_0 + \beta_1(Treat_s * Time - Law) + \beta_2 Time - Law + X_{ist}^{'}\beta_3 + \tau_{st}^{'}\beta_4 + \delta_s + \gamma_t + \mu_{ist} \quad (2)$$

$Treat_s$ is an indicator variable for the treatment group and $Time - Law$ is a linear time trend centered around the month and year that a state passes a medical marijuana law. For states that do not pass an MML, we randomly assign an MML passage date and center the data around this 'false' effective date in a comparable manner. We do not include state-specific linear interview wave trends in Equation 2. Such trends may absorb differences in trends for passing, and not passing, states which could lead us to falsely conclude that these two groups of states moved in parallel pre-MML. We view a model without state trends as a more conservative test of parallel trends than a model with trends. However, in unreported analyses we have estimated an augmented version of Equation 2 that includes state-specific wave trends. These results are not appreciably different than those reported in the manuscript and are available on request from the corresponding author.

Results of the parallel trends tests are reported in Tables 5 (health) and 6 (labor supply). Overall, while we do observe that some of the estimated β_1 coefficients are statistically different zero, we argue that the parallel trends test results do not invalidate the ability of our data to recover causal estimates. First, in the majority of regressions (12/16), the coefficient estimate of β_1 is not statistically different from zero. Second, in two of the four regressions in which the coefficient estimate of β_1 is statistically different from zero (probability of reporting pain and hours worked per week in the qualifying sample), the sign works *against* our ability

to detect MML effects (Simon, Soni, & Cawley, 2016). For example, using Equation 1 we document that, post-MML, the probability of reporting pain within the qualifying sample declines, but the coefficient estimate for β_1 in Equation 2 is positive, suggesting that chronic pain was increasing in treatment states relative to comparison states in the pre-MML period. Combining these two estimates suggests that we may understate the effect of MML passage on chronic pain and conditional hours worked in Equation 1, at least within the qualifying sample. While the estimates for β_1 in both of the depressive symptoms regressions are precisely estimated and positive in sign which may suggest that MML-passing states may have been experiencing worsening mental health conditions prior to the law passage, but we recovered no evidence that MML passage influenced this outcome in Equation 1. Thus, we do not make any strong statements regarding the relationships between MML passage and depression among older adults.

6.2 Endogeneity of the qualifying sample

A potential concern with our qualifying sample is that passage of an MML may alter the number of HRS respondents reporting qualifying conditions. Such behaviors would imply that we are stratifying our analysis sample on an endogenous variable which can lead to conditional-on-positive bias in regression coefficients (Angrist & Pischke, 2009). To explore this possibility, we regress the probability of being in the qualifying sample on the MML variable and other controls in Equation 1. Results are reported in Table 7. We find no statistically significant evidence that MMLs affect the probability of being in the qualifying sample. The coefficient estimate, while imprecise, carries a negative sign and is small relative to the baseline proportion (-0.01 vs. 0.55).

6.3 Migration

A related concern is program induced migration (Moffitt, 1992). That is, older adults may move to a state with an MML to take advantage of the ability to use medical marijuana without legal consequences. Such behavior, if present, could lead to bias in our coefficient estimates. To test for such migration patterns in our samples, we regress the probability that an HRS respondent migrated across state lines between interviews on the MML indicator and other controls in Equation 1. Results are reported in Table 7 and suggest that passage of an MML reduces the likelihood that a respondent moves by 0.7 percentage points (30.4% relative

to the baseline proportion of 0.023[28]) in the full sample; we do not observe statistically significant evidence of such migration patterns in the qualifying sample. Thus, we interpret these findings to imply that some of our findings, at least within the full sample, may be driven by residents remaining in a state with an MML, when they might otherwise chose to move, to consume the product legally. Importantly for our analysis, the absolute value of the migration coefficient estimate is considerably smaller than the absolute value of the health and labor supply coefficient estimates, indicating that our results cannot be fully explained by migration.

6.4 Additional robustness checks

We conduct several robustness checks that we report in the text for brevity, but that are available on request. Our identification strategy assumes that the changes in labor supply outcomes observed after states pass MMLs are driven by the laws themselves, and not an unobserved third factor.[29] We test this hypothesis by conducting a *Monte Carlo* simulation in which we randomly assign with replacement actual state legislative histories to our 50 states and DC, and estimate the effect of these false laws. Across 100 simulations, our mean point estimates are small and statistically indistinguishable from zero in all regressions.

We have estimated a number of alternative specifications including use of respondent fixed effects, restricting our analysis population to adults under 75 (i.e., respondents most likely to work), allowing for a year lag between the passage of an MML and our outcomes, excluding California (this state was the first state to pass an MML and represents a disproportionately large share of the sample), and excluding state-specific linear wave trends. Results generated in these alternative specifications are qualitatively the same as our main results.

Given gender differences in terms of health (e.g., women are more likely to experience mental health problems than men (Substance Abuse and Mental Health Services Administration, 2014)) and labor supply (i.e., men are more likely to work than women, particularly in an older sample such as we analyze in the HRS, see for example Banerjee and Blau (2016)), we have estimated separate regressions for men and women. We find interesting heterogeneity in health effects across gender. Post-MML, both reported pain and depressive symptoms decline among men, but not women, in passing states. However, women, but not men, experience improvements in SAH post-MML. In terms of labor supply, the stratified

[28]We note that the relative effect size is large, but we suspect that this large relative effect is driven by the fact that few older adults in our sample move across state lines.

[29]Such a third factor would have to follow the same rollout pattern across states as the MMLs that we study. We are not aware of such a third factor.

regressions suggest that the labor supply effects are stronger for men than for women, but both groups appear to increase labor supply post-MML.

Finally, we have used alternative coding schemes for MMLs (i.e., Pacula et al. (2015) and Wen et al. (2015)) and explored heterogeneity in MMLs (e.g., MMLs that allow legal access through home cultivation or dispensaries). Results are broadly comparable to those that we report in the manuscript.

7 Discussion

In this study we provide new information to the current policy debate surrounding legalization of marijuana for medical purposes through state regulations. Specifically, we explore the effects of state medical marijuana laws (MMLs) on older adult health and labor supply outcomes. First, we document that reported chronic pain declines and overall assessments of one's health improve post-MML among older adults. More specifically, post-MML the probability of reporting pain declines by 0.6% and the probability of reporting one's health as very good or excellent increases by 3.4%.[30] These findings suggest that access to medical marijuana through MMLs allows, at least some, older adults to better manage symptoms associated with chronic health conditions. Second, we find that MML passage allows older adults who are currently working to increase their labor supply, but we do not find evidence that MMLs allows older adults to re-enter the labor market. In particular, we find that passage of an MML increases the probability of working full time and the number of hours worked per week (among working adults) both increase by 3%. Finally, health and labor supply effects are even larger among older adults who are likely to use marijuana for medical purposes based on their health histories.

A key concern with marijuana regulation is that expanded access will promote recreational, and not medical, use of the product. While our study cannot fully address this important question, our estimates can bring some evidence to bear for the older adult population. The fact that we identify improvements in health outcomes that plausibly capture symptom burden (i.e., reported pain and overall health assessments) and increases in labor supply suggests that, even if some older adults do use marijuana obtained following passage of an MML recreationally, on average passage of an MML and the ensuing changes in health and labor supply confers important benefits to some older adults.

[30] As discussed earlier in the manuscript, the MML coefficient estimate is imprecise in the pain regression in the full sample.

We can compare our findings with previous studies that examine the labor market effects of MML passage. (i) Our findings are in line with Ullman (2016) who shows that, post-MML, work absence decline. (ii) Sabia and Nguyen (2016) finds no change in employment propensity following passage of an MML, which is comparable to our null findings for any employment. However, while we document that older adults increase labor supply along the intensive margin (defined as full time work and conditional hours worked) post-MML, Sabia and Nguyen (2016) find no statistically significant evidence that conditional hours worked increase. We hypothesize that our focus on an older sample of workers than Sabia and Nguyen (2016) may explain this divergence in findings: we examine workers who are 50 years and older while Sabia and Nguyen (2016) examine workers through age 64. Our analysis (unreported, but available on request) of the Annual Social and Economic Supplement to the Current Population Survey 1992-2012 suggests that 48% of adults 50 years and older and 24% of adults ages 65 to 75 years report being in the labor force.[31] Thus, a non-trvial share of older workers are in the labor force and may increase their labor supply following passage of an MML. Moreover, as noted ealier in the manuscript, older workers are the types of workers who are most likely to experience many of the the health conditions whose symptoms may be effectively treated by medical marijuana, suggesting that these workers are precisely the workers one would expect to observe positive labor supply effects. Collectively, these three studies shed important light on the full effects of MML passage on the labor market.

Our study has limitations. (i) Our sample is potentially vulnerable to survivor bias, that is we only observe the sample of older adults who are cognitively and physically able to complete their own interviews. (ii) Our identification strategy only uses variation in MMLs for those states that implemented such laws during our study period. (iii) As is the case in all other economics studies examining MML effects of which we are aware, we lack data on medical marijuana use in the HRS and our results have an ITT interpretation. (iv) We lack data on all health conditions for which medical marijuana may be an effective treatment for alleviating painful symptoms (e.g., anxiety, nausea).

The policy debate surrounding legalization of marijuana, for medical or recreational purposes, is fierce. In particular, with the Trump Administration's proposal to allow the Rohrabacher-Farr Amendment (2014) to expire raises new concerns among medical marijuana advocates and at the same time offers hope for critics who would like to curtail all marijuana access through regulation. Policymakers must carefully weigh the costs and the

[31]For comparison, our analysis suggests that 67% of all adults 16 years and older report being in the labor force.

benefits of such legalization. We provide evidence that there may be benefits in terms of the health and labor supply of older adults, a population that, based on clinical anecdotal evidence, has elevated need for medications that can reduce painful symptoms associated with a range of health conditions and is plausibly using marijuana medically. Taken in combination with findings that MMLs may reduce body weight (Sabia et al., 2017), improve physical well-being (Sabia et al., 2017), reduce suicide rates among some sub-populations (Anderson et al., 2014), lower opioid-related overdoses (Bachhuber et al., 2014; Powell et al., 2015), and reduce alcohol-related traffic accidents (Anderson et al., 2013), our findings suggest that there are potentially important social benefits to MMLs that must be considered in policy decisions regarding regulation of medical marijuana.

Table 1: State medical marijuana laws 1996-2017

State	Effective date
Alaska	3/1999
Arizona	4/2011
Arkansas	11/2016
California	11/1996
Colorado	6/2001
Connecticut	5/2012
DC	7/2010
Delaware	7/2011
Hawaii	12/2000
Illinois	1/2014
Maine	12/1999
Maryland	6/2014
Massachusetts	1/2013
Michigan	12/2008
Minnesota	5/2014
Montana	11/2004
Nevada	10/2001
New Hampshire	7/2013
New Jersey	10/2010
New Mexico	7/2007
New York	7/2014
North Dakota	12/2016
Oregon	12/1998
Ohio	8/2016
Pennsylvania	5/2016
Rhode Island	1/2006
Vermont	7/2004
Washington	11/1998
West Virginia	4/1998

Notes: Data source: Sabia and Nguyen (2016).

Table 2: Summary statistics: HRS 1992-2012

Sample:	1	2
Health outcomes		
Pain	0.31	0.43
Health limits work	0.29	0.39
SAH	0.41	0.32
Dep. symptoms	1.55	1.81
Labor supply outcomes		
Work	0.39	0.31
Work FT	0.26	0.19
Hours worked/wk (conditional on working)	36.70	34.75
MML		
Any	0.13	0.15
Individual characteristics		
Age	66.50	67.99
Less than high school	0.29	0.30
High school	0.31	0.32
White	0.80	0.80
African American	0.15	0.16
Other Race	0.05	0.04
Hispanic	0.09	0.09
State characteristics		
Marijuana decriminalized	0.32	0.32
Beer tax	0.26	0.27
Unemployment rate among adults 50+	0.042	0.042
Hourly wage among adults 50+	18.10	18.08
Minimum wage	5.77	6.00
State EITC as a proportion of the federal EITC	0.12	0.13
Max monthly food stamp benefit ($)	487.96	506.20
Democrat governor	0.46	0.46
N	183,032	101,112

Notes: Sample includes HRS respondents 51 years and older. Sample 1 = full sample. Sample 2 = qualifying sample.

Table 3: Effect of MML passage on older adult health outcomes: HRS 1992-2012

Outcome:	Pain		Health limits work		SAH		Dep. symptoms	
Sample:	1	2	1	2	1	2	1	2
Proportion/mean	0.31	0.43	0.29	0.39	0.41	0.32	1.55	1.81
MML	-0.002	-0.022**	-0.004	-0.008	0.014**	0.025**	-0.006	-0.023
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.04)
N	182,376	100,767	157,704	91,688	182,406	100,793	182,412	100,803

Notes: Sample 1 = full sample. Sample 2 = qualifying sample. All models estimated with an LPM (binary outcome) or LS (continuous outcome), and control for individual characteristics, state characteristics, state fixed effects, period fixed effects, and state-specific linear time trends. Standard errors clustered around the state and reported in parentheses. # significant at 10%, * significant at 5%, ** significant at 1%.

Table 4: Effect of MML passage on older adult labor supply outcomes: HRS 1992-2012

Outcome:	Work		Work FT		Hours worked/wk	
Sample:	1	2	1	2	1	2
Proportion/mean	0.39	0.31	0.26	0.19	36.7	34.8
MML	-0.003	-0.001	0.008*	0.011**	0.033*	0.060***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.02)	(0.02)
N	182,078	100,673	182,078	100,673	69,705	30,790

Notes: Sample 1 = full sample. Sample 2 = qualifying sample. Hours worked per week are conditional on any work and are log transformed. All models estimated with an LPM (binary outcome) or LS (continuous outcome), and control for individual characteristics, state characteristics, state fixed effects, period fixed effects, and state-specific linear time trends. Standard errors clustered around the state and reported in parentheses. # significant at 10%, * significant at 5%, ** significant at 1%.

Table 5: Parallel trends testing for older adult health outcomes: HRS 1992-2012

Outcome:	Pain		Health limits work		SAH		Dep. symptoms	
Sample:	1	2	1	2	1	2	1	2
Proportion/mean	0.31	0.43	0.29	0.39	0.41	0.32	1.55	1.81
MML*time	0.0001	0.0002*	0.0001	0.0001	0	0	0.0004*	0.0010**
	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0002)	(0.0003)
Time	-0.0027**	-0.0005	-0.0047**	-0.0042**	-0.0001	-0.0016*	0.0067*	0.0220**
	(0.0007)	(0.0010)	(0.0009)	(0.0010)	(0.0006)	(0.0009)	(0.0028)	(0.0025)
N	117,134	59,195	98,465	54,483	117,127	59,195	117,127	59,197

Notes: Sample 1 = full sample. Sample 2 = qualifying sample. All models estimated with an LPM (binary outcome) or LS (continuous outcome), and control for individual characteristics, state characteristics, state fixed effects, and period fixed effects. Standard errors clustered around the state and reported in parentheses. Only pre-MML data is included in the analysis. # significant at 10%, * significant at 5%, ** significant at 1%.

Table 6: Parallel trends testing for older adult labor supply outcomes: HRS 1992-2012

Outcome:	Work		Work FT		Hours worked/wk	
Sample:	1	2	1	2	1	2
Proportion/mean	0.39	0.31	0.26	0.19	36.7	34.8
MML*time	-0.0001	0	0	0	0	-0.0003*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Time	0.0069**	0.0035**	0.0083**	0.0060**	0.0060**	0.0126**
	(0.0006)	(0.0011)	(0.0006)	(0.0009)	(0.0009)	(0.0020)
N	116,969	59,133	116,969	59,133	59,133	18,907

Notes: Sample 1 = full sample. Sample 2 = qualifying sample. Hours worked per week are conditional on any work and are log transformed. All models estimated with an LPM (binary outcome) or LS (continuous outcome), and control for individual characteristics, state characteristics, state fixed effects, and period fixed effects. Standard errors clustered around the state and reported in parentheses. Only pre-MML data is included in the analysis. # significant at 10%, * significant at 5%, ** significant at 1%.

Table 7: Effect of MML passage on the probability of being in the qualifying sample and across-state migration among older adults: HRS 1992-2012

Outcome:	Qualifying sample	Move across state lines	
Sample:	1	1	2
Proportion/mean	0.55	0.023	0.023
MML	-0.0061	-0.0073*	-0.0071
	(0.0066)	(0.0043)	(0.0042)
N	182,518	148,764	89,117

Notes: Sample 1 = full sample. Sample 2 = qualifying sample. All models estimated with an LPM and control for individual characteristics, state characteristics, state fixed effects, period fixed effects, and state-specific linear time trends. Standard errors clustered around the state and reported in parentheses. # significant at 10%, * significant at 5%, ** significant at 1%.

References

Abouk, R., & Adams, S. (2017). *Examining the Relationship between Medical Marijuana Laws and Cardiovascular Deaths in the US.*

Ahmed, A. I., Elsen, G. A., Marck, M. A., Rikkert, O., & Marcel, G. (2014). Medicinal use of cannabis and cannabinoids in older adults: where is the evidence? *Journal of the American Geriatrics Society*, *62*(2), 410–411.

Anderson, D. M., Hansen, B., & Rees, D. I. (2013). Medical marijuana laws, traffic fatalities, and alcohol consumption. *Journal of Law and Economics*, *56*(2), 333–369.

Anderson, D. M., Hansen, B., & Rees, D. I. (2015). Medical marijuana laws and teen marijuana use. *American Law and Economics Review*, *17*(2), 495–528.

Anderson, D. M., Rees, D. I., & Sabia, J. J. (2014). Medical marijuana laws and suicides by gender and age. *American Journal of Public Health*, *104*(12), 2369–2376.

Angrist, J. D., & Pischke, J.-S. (2009). *Mostly harmless econometrics: An empiricist's companion.* Princeton University Press.

Apouey, B., & Clark, A. E. (2015). Winning big but feeling no better? The effect of lottery prizes on physical and mental health. *Health Economics*, *24*(5), 516-538.

Atlas, S. J., & Skinner, J. S. (2009). *Education and the prevalence of pain* (Tech. Rep.). National Bureau of Economic Research.

Azofeifa, A. (2016). National estimates of marijuana use and related indicatorsnational survey on drug use and health, united states, 2002–2014. *MMWR. Surveillance Summaries*, *65*.

Bachhuber, M. A., Saloner, B., Cunningham, C. O., & Barry, C. L. (2014). Medical cannabis laws and opioid analgesic overdose mortality in the united states, 1999-2010. *JAMA Internal Medicine*, *174*(10), 1668–1673.

Banerjee, S., & Blau, D. (2016). Employment trends by age in the united states why are older workers different? *Journal of Human Resources*, *51*(1), 163–199.

Barbour, K. E. (2017). Vital signs: prevalence of doctor-diagnosed arthritis and arthritis-attributable activity limitationunited states, 2013–2015. *MMWR. Morbidity and Mortality Weekly Report*, *66*.

Benjamins, M. R., Hummer, R. A., Eberstein, I. W., & Nam, C. B. (2004). Self-reported health and adult mortality risk: An analysis of cause-specific mortality. *Social Science & Medicine*, *59*(6), 1297-1306.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *Quarterly Journal of Economics*, *119*(1).

Bilkei-Gorzo, A., Albayram, O., Draffehn, A., Michel, K., Piyanova, A., Oppenheimer, H., ... others (2017). A chronic low dose of [delta] 9-tetrahydrocannabinol (thc) restores cognitive function in old mice. *Nature Medicine*, *23*, 782787.

Bradford, A. C., & Bradford, W. D. (2016). Medical marijuana laws reduce prescription medication use in medicare part d. *Health Affairs*, *35*(7), 1230-1236.

Bradford, A. C., & Bradford, W. D. (2017). Medical marijuana laws may be associated with a decline in the number of prescriptions for medicaid enrollees. *Health Affairs*.

Case, A., & Deaton, A. S. (2005). Broken down by work and sex: How our health declines. In *Analyses in the economics of aging* (pp. 185–212). University of Chicago Press.

Chau, D. L., Walker, V., Pai, L., & Cho, L. M. (2008). Opiates and elderly: Use and side effects. *Clinical Interventions in Aging*, *3*(2), 273.

Choi, A. (2014). *The impact of medical marijuana laws on marijuana use and other risky health behaviors.* American Society of Health Economists.

Choi, A., Dave, D., & Sabia, J. (2016). *Smoke gets in your eyes: Medical marijuana laws and tobacco use* (NBER Working Paper Series No. 22554). National Bureau of Economic Research.

Chu, Y.-W. L. (2014). The effects of medical marijuana laws on illegal marijuana use. *Journal of Health Economics*, *38*, 43–61.

Chu, Y.-W. L. (2015). Do medical marijuana laws increase hard-drug use? *The Journal of Law and Economics*, *58*(2), 481–517.

Datta Gupta, N., & Larsen, M. (2010). The impact of health on individual retirement plans: Self-reported versus diagnostic measures. *Health Economics*, *19*(7), 792–813.

Dwyer, D. S., & Mitchell, O. S. (1999). Health problems as determinants of retirement: Are self-rated measures endogenous? *Journal of Health Economics*, *18*(2), 173–193.

Fairman, B. J. (2016). Trends in registered medical marijuana participation across 13 usstates and district of columbia. *Drug and Alcohol Dependence*, *159*, 7279.

Garthwaite, C. L. (2012, July). The economic benefits of pharmaceutical innovations: The case of cox-2 inhibitors. *American Economic Journal: Applied Economics*, *4*(3), 116-137.

Gordon, M. O., Beiser, J. A., Brandt, J. D., Heuer, D. K., Higginbotham, E. J., Johnson, C. A., ... others (2002). The ocular hypertension treatment study: baseline factors that predict the onset of primary open-angle glaucoma. *Archives of Ophthalmology*, *120*(6), 714–720.

Hill, K. P. (2015). Medical marijuana for treatment of chronic pain and other medical and

psychiatric problems: a clinical review. *Journal of the American Medical Association*, *313*(24), 2474–2483.

Horn, B. P., Maclean, J. C., & Strain, M. R. (2017). Do minimum wage increases influence worker health? *Economic Inquiry*, *In Press*.

Ilgen, M. A., Bohnert, K., Kleinberg, F., Jannausch, M., Bohnert, A. S., Walton, M., ... Blow, F. C. (2013). Characteristics of adults seeking medical marijuana certification. *Drug and Alcohol Dependence*, *132*, 654659.

Joy, J. E., Watson, S. J., & Benson, J. A. (1999). *Marijuana and medicine: Assessing the science base* (Tech. Rep.). National Academies Press.

Kaila-Kangas, L., Haukka, E., Miranda, H., Kivekäs, T., Ahola, K., Luukkonen, R., ... Leino-Arjas, P. (2014). Common mental and musculoskeletal disorders as predictors of disability retirement among finns. *Journal of Affective Disorders*, *165*, 38–44.

Kamaleri, Y., Natvig, B., Ihlebaek, C. M., & Bruusgaard, D. (2009). Does the number of musculoskeletal pain sites predict work disability? a 14-year prospective study. *European Journal of Paediatric Neurologyain*, *13*(4), 426–430.

Kapteyn, A., Smith, J. P., & Van Soest, A. (2008). Dynamics of work disability and pain. *Journal of Health Economics*, *27*(2), 496–509.

Kaskie, B., Ayyagari, P., Milavetz, G., Shane, D., & Arora, K. (2017). The increasing use of cannabis among older americans: A public health crisis or viable policy alternative? *The Gerontologist*, gnw166.

Leske, M. C., Wu, S.-Y., Hennis, A., Honkanen, R., Nemesure, B., Group, B. S., et al. (2008). Risk factors for incident open-angle glaucoma: the barbados eye studies. *Ophthalmology*, *115*(1), 85–93.

Longo, L. P., & Johnson, B. (2000). Addiction: Part i. benzodiazepines-side effects, abuse risk and alternatives. *American Family Physician*, *61*(7), 2121–2128.

Lynch, M. E., & Campbell, F. (2011). Cannabinoids for treatment of chronic non-cancer pain; a systematic review of randomized trials. *British Journal of Clinical Pharmacology*, *72*(5), 735744.

Maclean, J. C. (2013). The health effects of leaving school in a bad economy. *The Journal of Health Economics*, *32*(5), 951-964.

Maclean, J. C., Webber, D., French, M. T., & Ettner, S. L. (2015). The health consequences of adverse labor market events: Evidence from panel data. *Industrial Relations*, *54*(3), 478-498.

McGarry, K. (2004). Health and retirement do changes in health affect retirement expecta-

tions? *Journal of Human Resources*, *39*(3), 624–648.

McInerney, M., Mellor, J. M., & Nicholas, L. H. (2013). Recession depression: Mental health effects of the 2008 stock market crash. *Journal of Health Economics*, *32*(6), 1090-1104.

Miilunpalo, S., Vuori, I., Oja, P., Pasanen, M., & Urponen, H. (1997). Self-rated health status as a health measure: The predictive value of self-reported health status on the use of physician services and on mortality in the working-age population. *Journal of Clinical Epidemiology*, *50*(5), 517-528.

Miranda, H., Kaila-Kangas, L., Heliövaara, M., Leino-Arjas, P., Haukka, E., Liira, J., & Viikari-Juntura, E. (2010). Musculoskeletal pain at multiple sites and its effects on work ability in a general working population. *Occupational and Environmental Medicine*, *67*(7), 449–455.

Moffitt, R. (1992). Incentive effects of the us welfare system: A review. *Journal of Economic Literature*, *30*(1), 1–61.

Morgan, K. (2003). Daytime activity and risk factors for late-life insomnia. *Journal of Sleep Research*, *12*(3), 231–238.

Nahin, R. L. (2015). Estimates of pain prevalence and severity in adults: United states, 2012. *The Journal of Pain*, *16*(8), 769–780.

National Institutes of Health. (2011). *Chronic pain: Symptoms, diagnosis, & treatment* (Vol. 6; Tech. Rep. No. 1). National Institutes of Health.

Nielsen, T. H. (2016). The relationship between self-rated health and hospital records. *Health Economics*, *25*(4), 497–512.

Nunberg, H., Kilmer, B., Pacula, R. L., & Burgdorf, J. R. (2011). An analysis of applicants presenting to a medical marijuana specialty practice in california. *Journal of Drug Policy Analysis*, *4*(1). (Article 1)

Ortman, J. M., Velkoff, V. A., Hogan, H., et al. (2014). *An aging nation: The older population in the united states* (Tech. Rep.). United States Census Bureau.

Pacula, R. L., Chriqui, J. F., & King, J. (2003). *Marijuana decriminalization: What does it mean in the united states?* [NBER Working Paper Series].

Pacula, R. L., Powell, D., Heaton, P., & Sevigny, E. L. (2015). Assessing the effects of medical marijuana laws on marijuana use: the devil is in the details. *Journal of Policy Analysis and Management*, *34*(1), 7–31.

Porter, M. E. (2010). What is value in health care? *New England Journal of Medicine*, *363*(26), 2477–2481.

Powell, D., Pacula, R. L., & Jacobson, M. (2015). *Do medical marijuana laws reduce*

addictions and deaths related to pain killers? (National Buruea of Economic Research Working Paper Series 21345)

Radloff, L. S. (1977). The ces-d scale. *Applied Psychological Measurement*, *1*(3), 385-401.

Reinarman, C., Nunberg, H., Lanthier, F., & Heddleston, T. (2011). Who are medical marijuana patients? population characteristics from nine california assessment clinics. *Journal of Psychoactive Drugs*, *43*(2), 128-135.

Saastamoinen, P., Laaksonen, M., Kääriä, S.-M., Lallukka, T., Leino-Arjas, P., Rahkonen, O., & Lahelma, E. (2012). Pain and disability retirement: a prospective cohort study. *Pain*, *153*(3), 526–531.

Sabia, J. J., & Nguyen, T. T. (2016). *The effect of medical marijuana laws on labor market outcomes* (IZA Discussion Paper No. 9831). IZA.

Sabia, J. J., Swigert, J., & Young, T. (2017). The effect of medical marijuana laws on body weight. *Health Economics*, *26*, 6-34.

Sallan, S. E., Cronin, C., Zelen, M., & Zinberg, N. E. (1980). Antiemetics in patients receiving chemotherapy for cancer: A randomized comparison of delta-9-tetrahydrocannabinol and prochlorperazine. *New England Journal of Medicine*, *302*(3), 135–138.

Sansone, R. A., & Sansone, L. A. (2008). Pain, pain, go away: Antidepressants and pain management. *Psychiatry*, *5*(12), 1619.

Sevigny, E. L., Pacula, R. L., & Heaton, P. (2014). The effects of medical marijuana laws on potency. *International Journal of Drug Policy*, *25*(2), 308–319.

Simon, K., Soni, A., & Cawley, J. (2016). *The impact of health insurance on preventive care and health behaviors: Evidence from the 2014 aca medicaid expansions* (Tech. Rep. No. 22265). National Bureau of Economic Research.

Stewart, W. F., Ricci, J. A., Chee, E., Morganstein, D., & Lipton, R. (2003). Lost productive time and cost due to common pain conditions in the us workforce. *Journal of the American Medical Association*, *290*(18), 2443–2454.

Stith, S. S., & Vigil, J. M. (2016). Federal barriers to cannabis research. *Science*, *352*(6290), 1182.

Substance Abuse and Mental Health Services Administration. (2014). *Results from the 2013 national survey on drug use and health: Summary of national findings* (NSDUH Series No. H-48). Substance Abuse and Mental Health Services Administration.

Swegle, J. M., & Logemann, C. (2006). Management of common opioid-induced adverse effects. *American Family Physician*, *74*(8), 1347-1354.

Szarvas, S., Harmon, D., & Murphy, D. (2003). Neuraxial opioid-induced pruritus: A review.

Journal of Clinical Anesthesia, *15*(3), 234–239.

Tian, H., Robinson, R. L., & Sturm, R. (2005). Labor market, financial, insurance and disability outcomes among near elderly americans with depression and pain. *Journal of Mental Health Policy and Economics*, *8*(4), 219.

Troutt, W. D., & DiDonato, M. D. (2015). Medical cannabis in arizona: Patient characteristics, perceptions, and impressions of medical cannabis legalization. *Journal of Psychoactive Drugs*, *47*(4), 259266.

Turvey, C. L., Wallace, R. B., & Herzog, R. (1999). A revised ces-d measure of depressive symptoms and a dsm-based measure of major depressive episodes in the elderly. *International Psychogeriatrics*, *11*(2), 139–148.

Ullman, D. (2016). The effect of medical marijuana on sickness absence. *Health Economics*, *In Press*.

Unruh, M. L., Redline, S., An, M.-W., Buysse, D. J., Nieto, F. J., Yeh, J.-L., & Newman, A. B. (2008). Subjective and objective sleep quality and aging in the sleep heart health study. *Journal of the American Geriatrics Society*, *56*(7), 1218–1227.

Van Ours, J. C., & Williams, J. (2011). Cannabis use and mental health problems. *Journal of Applied Econometrics*, *26*(7), 1137–1156.

Van Ours, J. C., & Williams, J. (2012). The effects of cannabis use on physical and mental health. *Journal of Health Economics*, *31*(4), 564–577.

Volkow, N. D., Swanson, J. M., Evins, A. E., DeLisi, L. E., Meier, M. H., Gonzalez, R., ... Baler, R. (2016). Effects of cannabis use on human behavior, including cognition, motivation, and psychosis: A review. *JAMA Psychiatry*, *73*(3), 292–297.

Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics*, *42*, 64–80.

Whiting, P. F., Wolff, R. F., Deshpande, S., Di Nisio, M., Duffy, S., Hernandez, A. V., ... others (2015). Cannabinoids for medical use: a systematic review and meta-analysis. *Journal of the American Medical Association*, *313*(24), 2456–2473.

Williams, A. R., Olfson, M., Kim, J. H., Martins, S. S., & Kleber, H. D. (2016). Older, less regulated medical marijuana programs have much greater enrollment rates than newer medicalized programs. *Health Affairs*, *35*(3), 480-488.

Yi, E. (2015). Medical marijuana use among older adults: A systematic review. *Gerontologist*, *55*, 672–672.