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SEX, DRUGS, AND BABY BOOMS:
CAN BEHAVIOR OVERCOME BIOLOGY?

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ABSTRACT

We study the behavioral changes due to marijuana consumption on fertility and its key mechanisms, as opposed to physiological changes. We can employ several large proprietary data sets, including the 1997 National Longitudinal Survey of Youth, Nielsen Retail Scanner database, as well as the Vital Statistics Natality files and apply a differences-in-differences approach by exploiting the timing of the introduction of medical marijuana laws among states. We first replicate the earlier literature by showing that marijuana use increases after the passage of medical marijuana laws. Our novel results reveal that birth rates increased after the passage of a law corresponding to increased frequency of sexual intercourse, decreased purchase of condoms and suggestive evidence on decreased condom use during sex. More sex and less contraceptive use may be attributed to behavioral responses such as increased attention to the immediate hedonic effects of sexual contact, delayed discounting and ignoring costs associated with risky sex. These findings are consistent with a large observational literature linking marijuana use with increased sexual activity and multiple partners. Our findings are robust to a broad set of tests.

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1. Introduction

While exceptions may occur in every discipline, in sciences such as biology, chemistry, or physics causal links are seen as a truth clad in iron. There is, essentially, a deterministic view on the average predictions of these disciplines. This is not the case in the social sciences, where claiming any causal link is particularly difficult as data are difficult to come by and are noisy, empirical techniques depend on strict assumptions, and results tend to be not robust enough. While hard and soft sciences are frequently perceived to move in parallel worlds they sometimes intersect, which potentially allow researchers to study specific questions from these two perspectives and thus help provide relevant insights, comparisons, and contributions that may enhance the understanding of the issue under analysis. Fertility is a topic where one finds such an intersection between hard and soft sciences, as there has been a long tradition to understand how some substances may impact both changes in sexual behavior as well as the biological propensity for child bearing.

In recent years, and largely because of the mainstreaming of marijuana use, the medical and biological literatures have placed intense scrutiny on how this substance may impact fertility by focusing on the specific physiological changes that occur due to its use, as marijuana use may impact hormones related to fertility. As a result of this research, there is some consensus that cannabis-related compounds negatively impact both male and female reproductive physiology. In the case of men these compounds disrupt some important biological connections in the body, which result in a significant reduction of hormones, a dramatic decrease of plasma testosterone levels as well as a significantly reduction in semen volume, sperm count, sperm motility, loss of libido, and impotence. In the case of women, the active component in cannabis disrupts the menstrual cycle, suppresses egg production, and impairs embryo implantation and development (e.g., Bari et al., 2011; Djernis et al., 2015; Fronczak et al., 2012).

Research in the hard sciences appears to have established a negative causal link between cannabis and reproductive likelihood through physiological mechanisms. However, this likely tells part of the story only, as drugs in general and cannabis in particular may also impact attitudes, perceptions, and ultimately the behavior of individuals. Indeed, conventional wisdom suggests that mood-enhancing drugs and sex are complements. In the specific case of marijuana, it is typically believed that its consumption heightens sensory perception, increases relaxation, reduces stress and diminishes anxiety (e.g., Palamar et al, 2018). It is reasonable to expect that attitudes and perception towards sexual activity may be impacted as well. Enhanced senses may contribute to an increase in sexual activity. A feeling of relaxation may change attitudes toward taking sexual risks by becoming less concerned about the consequences of sexual intercourse, including reducing protection or taking on more sexual partners. Cannabis consumption may have a direct bearing on attitudes and perception towards sexual activity as well as on the risk associated to it all of which may be directly related to fertility impacts. Overall, it is unclear whether any potential behavioral changes in individuals may help compensate or even overcompensate the likely reduction due to physiological mechanisms, so that instead of a reduction, as predicted by the hard sciences, we may end up observing an increase in fertility rates. In other words, it is unclear whether behavior may overcome biology through changes in sex frequency and risk factors.

In this paper we focus on the link between cannabis and fertility as well as its potential key behavioral mechanisms by exploiting the exogenous variations in medical marijuana laws (MMLs). In particular our approach is to seek a causal relationship between the legalization of medical marijuana and fertility rates by exploiting differences in the timing of the change of marijuana laws among states. We adopt a difference-in-difference (DID) research design by estimating a reduced-form model conditioning on county and year-quarter fixed effects while also controlling for state-specific time trends. The latter allows for different trends in each state and thus relax the parallel trend assumption that is required in the DID approach. We take clues from the associational evidence of the medical literature, which has studied the correlation between marijuana and increased sexual pleasure and relaxation, and we focus on the potential mechanisms that may contribute to the increase in fertility rates. In particular, we look at increases in the frequency of sexual activity and risky sexual behavior, derived from heightened pleasure or some impairment in judgment. Previous studies on these mechanisms are rather limited in terms of sample size and representativeness, and have rarely been published in the economic literature; and most if not all focus on correlation only (e.g., Sarvet, et al., 2018; Sun and Eisenberg, 2017). In fact, to our knowledge, there is not a single empirical study that provides causal evidence between marijuana use, sexual behavior, and fertility rates.

To understand relationship between marijuana, fertility, and sexual behavior; we gathered data from multiple sources, many of which were restricted use. Our main findings show a consistent relationship across three large, restricted data sets. First, to study fertility we use the county geo-coded Vital Statistics Natality files for years 2005–2014, which we merge onto the SEER population counts data to calculate the general birth rate in a county-year-quarter, defined as the total number of births in a county in each year-quarter divided by population counts on the population of women ages 15 to 44 in their county of residence. To understand the relationship between marijuana use, sexual activity and risk taking in sex, we employ the restricted use, geo-coded, National Longitudinal Survey of Youth 1997 (NLSY97), from years 2005 to 2011.[1] The NLSY97 allows us to both confirm the effects found in the earlier literature that medical marijuana laws increase marijuana use in adults and to demonstrate that such laws are associated with increased sexual activity. Additionally, we test in the NLSY97 the degree to which MMLs change sexual risk-taking behavior as proxied by sex with strangers and condom use. While we find some suggestive evidence that MMLs decrease condom use, small sample sizes in this data set means statistical power is limited. Therefore, we supplement this analysis with data from the Nielsen Retail Scanner database on monthly purchases of condoms in grocery, convenience, drug, or mass distribution stores in US counties for the period 2006-2014 in order to better understand the relationship between MMLs and condom use. Additionally, data on the implementation of MMLs come from the Marijuana Policy Project (MPP) previous literature (e.g., Anderson et al., 2013 and 2015; Sabia et al., 2017).

We find that behavior trumps biology as we provide causal evidence on the impact of marijuana use on the general fertility rate and find that such causal link is positive and economically significant. In addition, we find increases in the frequency of intercourse as a mechanism that explains increased fertility rates. Changes in risk perception are another mechanism as we find a negative causal link between MMLs and the purchase of condoms. In particular, our results show increased birth rates coupled with a higher likelihood of an individual having sex and lower county level sales of condoms. In line with the medical literature, which is mostly based on correlation of small non-representative samples, the changes in sexual behavior that we document may be attributable to several factors. First, the earlier literature shows there might be effects on the extensive margin i.e. cannabis use may lead to early initiation of sex (Cavazos-Rehg et al., 2011; Heil et al., 2011; Tapert et al., 2001). This is further substantiated by van Gelder et al. (2011) finding that that drug users are on average younger than nonusers at first

[1] The NLSY97 is a nationally representative survey of a cohort of individuals conducted annually from 1997 to 2015 and includes information on detailed aspects of sexual activity and substance use of individuals as they develop from adolescents through their adulthood. The questions on marijuana use are reported continuously only through 2011; and then are not asked again until 2015. Likewise, questions on sexual behavior are only continuously asked from 2000 to 2011. We therefore only look at the NLSY from 2005 to 2011.

vaginal sex and are more likely to have engaged in risky sexual behavior in the previous year. Second, increased frequency for sexual intercourse is potentially due to a large literature linking marijuana use to multiple and casual partners (Basikin-Sommers et al, 2006; Grossman et al., 2004; LaBrie et al., 2005). Finally, a drop in sales of condoms may be attributed to lower use due to behavioral responses such as increased attention to immediate hedonic effects of sexual contact, delayed discounting and ignoring costs associated with risky sex (George and Koob, 2010, Vangsness et al., 2005, Kingree and Phan, 2002). To supplement this, we provide additional, albeit noisy evidence on individual condom use. Declines in condom use is consistent with evidence that substance use may affect contraception either directly or indirectly even if it does not immediately precede sexual intercourse: the latter being due to its earlier effects on partner selection and partner communication. If individuals are engaging with multiple and/or casual partners, these interactions are likely to be unplanned, resulting in lesser use of contraception. (Zabin and Hayward, 1994). Our findings are robust, as placebo, falsification tests, and event study analysis confirm a causal interpretation of the findings between MMLs, fertility rates with increased sexual activity as a main mechanism.

The paper is organized as follows. The next section provides a literature review. Section 3 introduces the data. Section 4 presents the empirical strategy and different estimation methods. In Section 5 we discuss results, provide evidence on mechanisms and apply several robustness checks. In Section 6 we discuss the magnitude of our findings including likely mechanisms for spillover effects. Finally, in the last section we provide a brief summary and conclusions.

2. What Do We Know?

2.1 Biological effects of marijuana use on fertility

Fertility rates can be impacted by altered hormone activity resulting from use of marijuana. In recent years the medical literature has provided strong evidence that cannabis use may be associated with reduced male fertility through impairment in semen quality (Sansone et al., 2018; du Plessis et al., 2015; Gundersen et al., 2015; Pacey et al, 2015), an increase in the percentage of motile sperm (Close et al., 1990), an increase in ejaculation problems, a reduction in sperm count, and impotence (Bari et al., 2017; Djernis, 2015). Similarly, in the case of female fertility, marijuana disrupts the menstrual cycle, suppresses egg production, and impairs embryo implantation and development (Bari, et al., 2017). There is also evidence of biological changes in the brain following the use of alcohol and marijuana. Substance use inhibits neural activity in the prefrontal cortex, the area of the brain responsible for planning for the future and integrating behavioral alternatives with context and long-term goals. Research shows that behavioral responses to substance use, such as increased attention to immediate hedonic effects of sexual contact, delayed discounting and ignoring costs associated with risky sex, can partially be attributed to these changes in neural activity in the brain (George and Koob, 2010, Vangsness et al., 2005).

2.2. Marijuana use and risky sexual behavior

In addition to any direct physiological effects, there are other links associated with sexual behavior and cannabis use. A host of studies, starting in the 1980s, shows a positive association between marijuana use and risky sexual behavior, though these studies fail to address potential selection biases. This extensive literature finds that substance use is positively associated with several sexual behaviors such as early initiation of sexual intercourse, multiple sexual partners, and engaging in intercourse without contraception. There are several types of risky behaviors resulting from substance use that can lead increased fertility and unwanted pregnancies. First, substance use can result in early sexual intercourse (Ramrakha et al, 2000; Tapert et al., 2001). For instance, Cavazos-Rehg et al. (2011) link teen marijuana use to greater probability of sexual intercourse and pregnancy.[2] Second, individuals are more likely to have multiple sexual partners (Basikin-Sommers et al, 2006). For example, Grossman et al (2004) suggest that cannabis may be employed as a way to "break the ice" with a new partner.[3] Third, marijuana use is associated with inconsistent or no condom use (Brooks et al., 2004; Shrier et al., 1997; Guo et al., 2002; Hittner

[2] Heil et al. (2011) also find that use of marijuana at the age of nineteen increases likelihood of subsequent unplanned pregnancy and, as a result, higher rates of abortion. In addition, they found evidence that women who use marijuana are at an increased likelihood of abortion independent of unplanned pregnancy rates.

[3] Likewise, LaBrie et al. (2005) also suggest that levels of substance use in conjunction with sexual activity differ across partner types, with substance use being more common with newer or less well-known partners. Anderson and Stein (2011) find that on days of sexual activity with casual partners, the likelihood of risky sex was 2.5 times higher when marijuana was used than when marijuana was not used. However, on days of sexual activity with regular partners, marijuana use had no effect on risky sex. In addition, a positive association exists between sexual assertiveness and length of sexual relationship, suggesting that women may be more sexually assertive with known partners compared with new partners (Mokoroff et al., 2009). Multiple or casual partners can hence increase the likelihood of risky sex. Alternatively, a teenager who chooses to have many sexual partners may use drugs and alcohol to cope with society's negative view of such behavior (Cooper et al., 1990). In effect, the teenager would consume these substances to lower the psychic costs of risky sex. Cooper et al. (1990) hence suggest that there can be reverse causality between drug use and multiple sexual partners.

and Kennington, 2008).[4] Specifically, studies suggest that marijuana use at the time of sexual activity reduces the likelihood of condom use (Bailey et al., 1998; Kingree and Betz, 2003; Kingree and Phan, 2002).[5]

The effect of marijuana on risky sex need not occur directly through impairing judgement or encouraging risky sexual behavior. Research on young adult relationships suggests that contraceptive use is greatest when sexual activity is planned and when partners have developed a close relationship (Zabin and Hayward, 1994). Substance use may affect these important determinants of birth control through influencing how a romantic relationship develops and the communication between two partners. Interestingly, this suggests that substance use may affect the use of contraception and sexual behavior even if it does not immediately precede sexual intercourse because of its earlier effects on partner selection and partner communication. In fact, there is evidence from experimental studies that verbal communication is impaired after marijuana consumption (e.g., Haney et al., 1999)[6].

While these studies provide mounting evidence of positive association between marijuana use and risky sexual behavior, causality is difficult to establish due to issues of endogeneity. Adolescent sexual behavior and substance use can depend on a set of personal and social behaviors, many of which are unmeasured. Thus, researchers need a credible empirical strategy in order to overcome this bias[7].

[4] In addition, several recent studies have assessed daily fluctuations in substance use (alcohol or marijuana) and condom use behavior (e.g. Leigh et al., 2008; Schroder et al., 2009; Anderson et al., 2011; Cooper, 2006), thus allowing for modeling of individual (within-person) effects, as well as situational and contextual factors, such as partner type.
[5] Earleywine (2002) suggests a woman, who is high on marijuana and faces a situation in which she needs to initiate or insist upon condom use, will be more likely to have unprotected sex than when not high. This can be a result of being more focused on the moment and the physical sensations (due to heightened sexual arousal and pleasure) and positive mood presented by the sexual situation, rather than thinking about potential future negative consequences of not using condoms (e.g. STIs, unwanted pregnancies, etc.).
[6] Marijuana use hence may decrease the ability to engage in effective communication about condom use e.g. negotiation and sexual assertiveness. Lower levels of sexual assertiveness have been associated with unprotected sex (frequency of condom use) and intentions to use condoms (Stoner et al., 2008; Morokoff et al., 2009; Parks et al., 2012).
[7] This is precisely why the causal nature of this relationship is not well established, with only a handful of studies attempting to establish causality and not just association (Rashad and Kaestner, 2004). To address this, Rees et al. (2001) use IV and bivariate probit models on data from NLSY97 and conclude that the link between substance use and sexual behavior found by previous researchers may not reflect causation. Their results suggest that the positive correlation between substance use and risky sexual behavior can, more often than not, be attributed to the influence of unobservables, yielding only weak evidence that marijuana and alcohol use influence sexual behavior.

2.3. Marijuana use and non-risky sexual behavior.

While there is an extensive literature on marijuana use and risky sex, a smaller literature also appreciates that marijuana consumption may directly lead to increased relaxation, arousal and enjoyment of sex. Regular marijuana users report a set of physiological and perceptual effects that are likely to influence sexual decision-making and perception. These include a sense of enhanced responsiveness to sexual touch, an increase in positive mood and relaxation, as well as an increase in strong emotions. Supporting this, animal studies show that using a cannabinoid compound to stimulate the same neuro receptors that process THC leads to copulation in previously non-sexually active rats (Canseco-Alba and Rodriguez-Manzo, 2012). In humans, low levels of cannabis use are associated with increased reported sexual arousal. While higher doses of marijuana eventually led to a diminished libido in men, both high and low doses of marijuana is associated with increased sexual proclivity in women (Gorzalka, Hill, and Chang, 2010; Koff, 1974; Bari et al., 2017; Djernis, 2015).

To the degree that medical marijuana relieves chronic pain, pain during sex, and improves life satisfaction, then it is natural that sexual activity could also increase. Consequently, with the liberalization of marijuana laws there has been a steep increase in cannabis products designed to improve sexual wellness, and use of marijuana in sexual therapy to remove psychological anxiety or physical pain associated with sex (Palamar, et al, 2018; Sun and Eisenberg, 2017). While this supports increased frequency of sexual activity there is a dearth of evidence (that we know of) connecting marijuana use to increased decisions to bear children. Therefore, we believe the most likely interpretation of declining condom use is that it reflects increase in risk taking during sex.

In summary, in spite of many attempts at establishing a link between marijuana and sexual-related activities, the related causal evidence is rail thin and rather weak. Moreover, the existing associational literature is also limited with the relationship predominantly studied in adolescents and young adults or in selected subpopulations and geographically concentrated areas. Unsurprisingly, the evidence on behavioral changes that marijuana use may produce on fertility is nonexistent, to our knowledge. The causal relationship being unknown, raises concerns about policy making and laws that relax substance use, in terms of their spillover effects on sexual behavior.

2.4 Medical marijuana laws, marijuana use, and other potential channels

Our identification strategy relies on medical marijuana laws (MMLs) in our sample increasing marijuana use. A growing literature on MMLs supports this assumption. Specifically, MMLs have been shown to increase the probability of marijuana use by 14-15% over the mean (e.g., Wen et al., 2015; Pacula et al, 2015). Wen et al. specifically show a substantial increase in reported marijuana use using the National Survey of Drug Use and Health (NSDUH) using similar variation to us in late adopting states from 2004 to 2012. There could be a variety of mechanisms by which this increased use of marijuana occurs. There could be direct effects of increased medical use, though the number of registered medical patients is relatively small, suggesting a large portion of increased marijuana use is not purely due to medical use. Alternatively, medical marijuana could be diverted to recreational use, though this is not the only way that non-patient users could increase use after MMLs. Medical marijuana laws could have nuanced impacts on the black market: for example, these laws decrease the price of high-quality black market marijuana by 26% (Anderson et. al, 2013), and may encourage dealers to focus marketing sales to adults instead of teens (Anderson et al, 2014). Finally, MMLs could embolden marginal users who see the liberalization of marijuana laws as a reflection of greater societal approval of marijuana use[8].

To that end we document a robust increase in marijuana among young adults following the passage of these laws using the NLSY97. We show through an event study analysis that this increase in use is not driven by a pre-trend. It is also recognized that states that allow home cultivation of marijuana may be particularly susceptible to recreational take-up. Therefore, following the earlier literature (Anderson et al, 2013), we show separate results assigning treatment based on the date any medical marijuana law is enacted, and for the date home cultivation is allowed (if ever), as well as heterogeneity in effects across other types of MMLs.

In this analysis we do not look at recreational legalization of marijuana for three reasons. First, most states legalized recreational marijuana late in our sample (from 2012 - 2014). Given the limitations of our restricted use birth certificate data: there would be a very limited post period for our findings. This is particularly true for fertility, which requires at least nine months after the passage of a law to observe effects. Second, there have been documented large cross border spillovers of recreational marijuana use (Hansen et al. 2018), making it unclear that a state level

[8] Other evidence of MMLs on illegal supply has shown that passage of a law potentially increases farmer output in local state markets and reduces demand for illegally imported marijuana, in turn reducing violent crime in states on the Mexican border, (Gavrilova et al, 2017).

difference in difference design using nearby states as controls is appropriate. Finally, the NLSY97 stops reporting yearly interviews in 2011, and any questions on marijuana use in 2013, limiting the available data for studying the effect of recreational marijuana laws on marijuana use, sex, and condom use.

3. Data

3.1 Data on marijuana laws

We exploit variation across states and over time in the implementation of MMLs. For this analysis we focus on the period 2004-2014.[9] Information on the exact date of enactment and implementation of MMLs come from the Marijuana Policy Project (MPP), the previous literature (e.g., Anderson et al., 2013 and 2015; Wen et al., 2015; Sabia et al., 2017), and specialized Internet websites. It has been noted in this literature that there is sometimes a lag between when a law is enacted in a state and the actual date of operation of dispensaries or otherwise when legally supplied marijuana becomes available (e.g., Choi et al., 2016; Anderson et al., 2018; Powell et al., 2018).[10] At the same time, monitoring and enforcement of marijuana use may change with enactment of a law even if other channels for legal supply are not yet in operation. Likewise, MMLs could make marginal users feel emboldened to begin use as soon as an MML passes. With this in mind, we take a parsimonious approach: showing our main results both assigning treatment based on whether any MML was passed and assigning treatment based on whether\when home cultivation is allowed in a state. We focus on home cultivation because it is one of the clearest avenues by which supply for recreational use could become available, in part due to the difficulties involved in states regulating home cultivators. Generally, we see larger effects on marijuana use

[9] We limit these years because they are the only ones we consistently have across all of our major datasets. While the NLSY97 starts in 1997: the majority of the respondents did not come to age until 2005, and since the earlier literature and our own tests show no effect on teen use of MMLs we cannot document first stage effects on marijuana use or sexual activity before this time. Likewise, while the Vital Statistics goes back further, the US standard birth certificate changed substantially in 2003 and without being able to document effects on sexual activity and marijuana use we decided to not look at fertility in this earlier period. Regardless, one of the advantages of focusing on the 2004-2014 period is that it limits our sample to recent MML changes, which is arguably most relevant for future policy predictions. Finally, we only have Nielsen data going back to 2006.

[10] For instance, although Connecticut passed a MML in 2012, home cultivation was not allowed and the first dispensary opened in 2014, only. Delaware passed a MML in 2011 but home cultivation was not allowed and the first dispensary did not open until 2015. New Hampshire passed a MML in 2013 but home cultivation was not allowed and the dispensary did not open until 2016. New Jersey passed a MML in 2010 but home cultivation was not allowed and the first dispensary did not open until 2012. New York passed a MML in 2014, but the first dispensary did not open until 2016.

and fertility in states that allow home cultivation. We have also replicated our analysis using the date when the first legal supply channel became available, defined as the date either that home cultivation is allowed, or as of the opening of the first dispensary or treatment center. In practice results based on "first legal supply available" were similar to assigning treatment based on date of home cultivation.

Table 1 presents a list of dates of when the medical marijuana law in a state first became effective, whether the state allows home cultivation, the date when the first dispensary or compassionate treatment center opened, and whether medical marijuana can be prescribed for non-specific pain symptoms. Unless otherwise noted, states that allowed home cultivation or had non-specific pain provisions, enacted these provisions at the same time the law was enacted. For reference, we also show the date that "legal supply first became available" as defined above. In some cases, a law is enacted outside of our sample while a provision is passed within the time frame of our sample. In this case we leave the date as "----", so that table 1 only shows variation from the passage of laws/provisions used in this study.

3.2 Birth Rates

The primary data on fertility are birth records from the restricted use Vital Statistics Natality files from the National Center for Health Statistics[11], geo-coded at the county level for cohorts conceived between 2004 and 2014 (birth certificate data years 2005-2014). The Vital Statistics contains information from all birth certificates in the U.S. such as birth outcomes, gestational length, and parental demographic information. We begin by calculating for each birth the estimated year and quarter of conception using gestational age as reported on the birth certificate. From there we construct the number of births for each county-year-quarter of conception, giving us conceptions beginning in the first quarter of 2004 and ranging to the third quarter of 2014. From this information we derive the numerator of the general fertility rate as the number of conceptions that result in a live birth in a given county-year-quarter cell. To calculate the denominator, we use county-level population estimates come from the SEER population provided by the National Cancer Institute.[12] Specifically, the denominator of the general fertility

[11] As compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

[12] These data were downloaded from the NBER website: http://www.nber.org/data/. A main advantage of SEER is that it is to our knowledge viewed as providing the best publically available county level population estimates in intercensal years.

rate is defined based on the population (in 1000s) of women of childbearing age (15 to 44) during the corresponding quarter-year of conception. Month and location of birth, together with gestational length, allow us to assign to each birthrate cell the status of MMLs at the quarter when the child was conceived. We assign treatment to conceptions that occurred the first full quarter after the passage of the law. We similarly construct subgroup specific fertility rates by taking subgroup counts of births from the vital statistics and dividing by the appropriate denominator from the SEER data.[13] However, we do not have SEER data counts by marital status or education so in this case we divide by the full population of women[14]. In our sample, the general fertility rate is 14.83 per 1000 women of child bearing age in a county-quarter. Summary statistics are presented in Table 2, Panel A.

3.3 Sexual Behavior and Marijuana Use

Data on marijuana use and sexual behavior are available from the National Longitudinal Survey of Youth 1997 (NLSY97). The NLSY97 is a nationally representative survey of a cohort of individuals who were 12-16 years of age in December 1996 and has been conducted annually from 1997 to 2011, and every two years afterwards. The survey includes information on many detailed aspects of individuals as they develop from adolescents through their adulthood. Using this dataset for our analysis presents at least two advantages. First, it includes detailed questions about sexual activity and substance use of the respondent. The survey asks about marijuana use and sex frequency in the previous 30 days. It also includes questions about the propensity to risk of the respondent with regards to sexual activity such as condom use and promiscuity.[15] The second advantage is that since respondents are followed over time we can control for individual unobserved heterogeneity that may be correlated with marijuana use and MMLs (Anderson et al.,

[13] For example, when constructing the Black fertility rates, we total the number of Black mothers and divide by the number of Black women in the appropriate county-year-quarter cell ages 15 to 14

[14] Mechanistically this means the marital status specific fertility rates will be lower than the general fertility rate. However, for our purposes we use this subgroup analysis mainly to compare effects across marital status groups or estimate effects relative to the mean.

[15] The specific questions are the following. For sexual frequency: "About how many times have you had sexual intercourse in the past four weeks?" This question has been asked continuously starting in 2000 until 2011. For marijuana use: "On how many days have you used marijuana in the last 30 days?" This question has been asked continuously from 1997 until 2011. For sex with strangers: "Since the last interview, have you had sex with someone who was a stranger to you?" This question has been asked continuously starting in 2000 until 2011. For condom use: "Thinking about all the times that you have had sexual intercourse since the last interview, about what percent of the time, from 0 to 100, have you or your sexual partner or partners used a condom?" This question has been asked continuously since 2002.

2015). One limitation of this dataset is that because the survey began with cohorts who were teenagers in 1997, in the survey years 2005-2011 our observations are on individuals that are no younger than 21 and no older than 30. Therefore, we only estimate effects on young adults in this dataset. However, because these ages represent peak child bearing years, this is arguably the most important margin corresponding with our fertility results.

For the NLSY97, using the date of the interview we can match each respondent to whether an MML was passed at the time of the reported behavior. Because the questions on marijuana consumption and sexual activity refer to the previous month, we match treatment to 30 days before the interview. For sexual activity, we create an indicator if the respondent had sexual intercourse once or more in the 30 days preceding the date of the interview, and an indicator for having sex three or more times. Jointly we felt these two variables captures different margins of the intensity of sexual activity across which marijuana use may affect behavior, but we have tested the robustness of these results to other definitions of sexual frequency.[16]

The NLSY97 data also allows us to observe other behaviors related to sex. To proxy for promiscuity, we create an indicator for reported sexual intercourse with a stranger since the past interview.[17] To capture likelihood of contraceptive use we look at reported condom use. Condom use is measured as the percent of the time the respondent, or their partner, used a condom during sexual intercourse since the previous interview. Unfortunately, we have very small sample sizes on condom use: this is due to low response rates and the fact that reports of condom use are by definition conditional on reported sexual activity since the last interview. There are roughly 6 times fewer observations for this outcome than the other outcomes in the NLSY97. Summary statistics are reported in Panel B of Table 2.

3.3 Retail Condom Sales

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[16] We also measure frequency of sexual activity as an indicator for having intercourse three times or more in the past month as well counts for the number of times of sexual intercourse (top-coded at 7 or more). Our results are generally consistent across these methods, though the "number of times" measure has larger standard errors, suggesting more precise impacts on the lower end of the distribution of sexual frequency.

[17] As with sexual frequency, we can precisely match the reported behavior to the timing of the laws. However, in this case because the behavior on condom use and promiscuity is reported for the time between the two interviews, we match the treatment variable to the period since the previous interview. In other words, the respondent is considered to be treated if starting from the date of the previous interview medical marijuana was legalized in her/his state of residence.

Because of the relatively small sample sizes in the NLSY97 and the fewer number of respondents to questions on birth control, we supplement the analysis on condom use by using the Nielsen Retail Scanner database to study whether MMLs had an effect on condom sales. While retail sales do not strictly represent behavioral use of condoms, sales also do not suffer from underreporting and measure error problems prevalent in self-reported data. Condom sales could decline with decreased use or decreases in sexual activity. However, given that we estimate increases in sexual activity, we interpret declines in condom sales as net of increased sex. We have access to store level data on condom sales observed in the scanner database for states before and after MMLs became effective. The database contains purchases of products in all categories for grocery, convenience, drug, or mass distribution stores across the United States for the period 2006-2014, including detailed product characteristics, price, and quantities for different condom types and brand. The Scanner data ensure a wide spatial coverage of sales across the 48 contiguous states of the US. Consistently with the analysis on birth rate, we aggregate sales data to the county-quarter level. Overall, we have sales data for more than two thousand US counties. Summary statistics are reported in Panel C of Table 2.

3.4 Covariates

We control for a set of time-varying covariates that could potentially influence sexual behavior and fertility and also be correlated with MMLs. The SEER population data are used to construct controls for the demographic composition of counties over time. Specifically, we include quarterly measures of the share of the population male, Hispanic, by race group (White, Black, Asian, and Other) age groups (0-19, 20-39, 40-64, 65 plus). We additionally control for state-level share of educational groups, which is not available in SEER but is provided by the ACS: (high school dropout, high school graduate, some college, and college educated). [18] Information on economic characteristics such as the unemployment rate and median household income comes from Local Area Unemployment Statistics and Small Area Income and Poverty Estimates. As described earlier, the NLSY97 includes detailed information on the demographic characteristics of the respondents. Therefore, in addition to controls for the demographic composition of the state/county, when using the NLSY97 we also include indicator variables for race, gender,

[18] Although county-level data is available in the ACS, a non-negligible number of counties are missing when we turn to the ACS. We thus prefer to rely on state-level data on share of the population by education group.

educational attainment, and age-in-years fixed effects.

We are also concerned with the existence of contemporaneous policies that may be correlated with an MMLs implementation. We are particularly concerned about policies that affect consumption of marijuana for reasons other than the legalization of medical use and policies that affect fertility. We address the first concern by creating dichotomous indicators for states that decriminalized and/or legalized the consumption of recreational marijuana. We also include annual state-level data on beer and cigarette tax rates.[19] Passage of the Affordable Care Act (ACA) allowed states to choose to expand Medicaid coverage, and Medicaid is a prominent provider of family planning services. We therefore created an indicator for the states that opted-into expanded Medicaid coverage in 2014. It is possible that more conservative states may be less likely to legalize medical marijuana and more likely to limit access to abortion. Recently several states have passed so called Targeted Regulation of Abortion Provider (TRAP) laws, which impose more stringent requirements on abortion clinics, making abortion less accessible (Jones et al., 2018). We control for the different components of these TRAP laws using data from the Policy Surveillance Program's website.[20] Summary statistics for all state-year level policies as well as all our individual and county level covariates are presented in Table A1.

4. Empirical Methodology

We estimate a Difference-in-Difference panel model to identify the impact of marijuana use on sexual behavior and fertility outcomes. Specifically, we estimate the following model:

$$y_{cst} = \beta MML_{st} + \phi_c + \gamma_t + \vartheta_s t + \boldsymbol{\pi}\mathbf{X}_{cst} + \eta_{cst}, \quad (1)$$

where y_{cst} is one of several outcomes related to either fertility, sexual behavior or marijuana use,[21] observed in county c, in state s, in time t. Time fixed effects are defined at the year-quarter level

[19] State cigarette and beer tax information is based on several sources: American Petroleum Institute, state revenue departments, Distilled Spirits Council of the U.S., Commerce Clearing House, Orzechowski and Walker's "Tax Burden on Tobacco", and the Tax Foundation.
[20] Data are available on LawAtlas.org; accessed on April 2018. These laws cover the regulation of licensing of provisions and accreditation (AFL), requirements for the ambulatory surgical centers (ASC), and hospitalization requirements (HR) for facilities providing abortion. Indeed, as a result of these more stringent regulations the number of clinics offering abortion has indeed decreased in states that have imposed these restrictions (Jones and Jerman, 2017).
[21] As discussed above in the data section, we explore the impacts of change in MMLs on several outcome variables. We use the NLSY97 data to investigate the effect on marijuana use and sexual frequency. We also use the NLSY97

across all datasets. *MML* is an indicator for whether in state s medical marijuana law is effective in time t, and β is the coefficient of interest. The treatment variable *MML* is equal to 1 if the state has either enacted legalized medical marijuana or one of its key provisions at time *t*. The terms ϕ_c represent geographic fixed effects (county in the vital statistics or state in the NLSY97), and γ_t represents time fixed effects (year-quarter of conception in the vital statistics or year-quarter of interview in the NLSY97). We also include state-specific time trends, $\vartheta_s t$, to control for systematic pre-trend differences in birth rates between treated and control states[22], as well as for unobservable state-level factors evolving over time at a constant rate. $\mathbf{X}_{cst}$ is a vector of control variables, that is, demographic, economic, and policy variables listed in the appendix, Table A1. In all models and datasets, the standard errors are clustered at the state level allowing for within state serial correlation (Bertrand et al., 2004). All regressions are weighted using sample weights for the NLSY97 regressions, and using county-year population for fertility and condom sales regressions.

Across our datasets we examine the sensitivity of the estimated parameter of interest, to including different sets of control variables in $\mathbf{X}_{cst}$. Given their importance to marijuana use and fertility in all specifications we control for laws for the decriminalization and legalization of recreational marijuana, as well as a rich set of controls for county demographic shares by race, ethnicity, age, and education as described in section 3.4 above and shown in Table A1. In our second specification, we then add the county unemployment rate and interactions between county demographic characteristics and the unemployment rate.[23] This is an important control since participation in the labor market affects the opportunity cost of childbearing and thus influences fertility rates (e.g., Adsera, 2004; Del Bono et al., 2012; Schaller, 2016). For our final and preferred specification, we include an additional rich set of policy and demographic relevant controls: state

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examine the impact on risky sexual behavior by focusing on the use of condom and having sexual intercourse with someone that is a stranger. The analysis on condom use is supplemented by looking at the effect of MMLs on the log of quarterly sales of condoms across U.S. counties. Finally, using the natality data we investigate the impacts on the general birth rate.

[22] We include state linear time trends in our main specification because in many cases the state level pre-period is somewhat longer than the post period (see table 1), making it more important to absorb trends over time. We also have run our results without linear trends and find that the coefficient estimates are almost identical to our preferred specification but that the standard errors are substantially larger. This supports the notion that there are trends over time in fertility and marijuana use that are unrelated to MMLs but add noise to our estimates. We show results on fertility without linear trends in appendix table A2.

[23] This allows for differential impacts of the demographic shares based on the other relative shares in the population and the unemployment rate, though including these terms have little overall effect on the coefficient of interest.

cigarette and beer tax variation, an indicator for expanding Medicaid under the ACA, TRAP laws, median county income, and all interactions between the various demographic covariates.

Unlike the fertility and retail scanner data, the NLSY97 has unique data related advantages and disadvantages that affect how we specify our models. First, we can include individual level covariates, such as age-in-year fixed effects, in addition to county demographic controls in all models (see section 3.5 above and Table A-1). Second, because the NLSY97 follows the same cohort of individuals over time, this data allows us to test our preferred specification for unobserved individual heterogeneity using individual fixed effects. We do not add individual fixed effects to the regressions on condom use because we only observe condom use for those who are sexually active which itself is changing with the laws.[24] Likewise, we are unable to reliably include state-linear trends in the condom use regressions.[25] Finally, since there is not a comprehensive set of counties in the NLSY97 we use state fixed effects instead of county fixed effects. Beyond these few differences, we match our specifications between our data sets.

4.1 Event Study Methodology

One way to verify the validity of our results is to visually check for differential trends in an event study. This method has the advantage of both verifying that there are no differential pre-trends and showing that the coefficients are identified off of changes that occur around the time of the policy. We estimate event studies using the following equation:

$$y_{cst} = \sum_{j=-7}^{4} \delta_j 1(\tau_{ct} = j) + \phi_c + \gamma_t + \vartheta_s t + \boldsymbol{\pi}\mathbf{X}_{cst} + \eta_{cst}, \quad (2)$$

where τ_{ct} indicates the event quarter-year, which takes value equal to one when an observation is j semesters away from the quarter the law became effective.[26] These event dummy variables

[24] In addition to making the individual fixed effect endogenous, this makes it unclear to us how to interpret within person differences in condom use. Specifically, if the marginally sexually active individual is more (or less) likely to use a condom due to marijuana this person is unobserved in the pre-period and therefore removed from identification when individual fixed effects are included.
[25] We did not feel that there were enough observations before and after the passage of MMLs to reliably estimate both quarter-year fixed effects and state-specific quarter-year linear trends, and therefore we dropped the trends from these regressions.
[26] We aggregate event time into six-month bins to reduce noise, particularly in the NLSY97, which has relatively small sample sizes. However, we find qualitative similar patterns to putting event time in quarters and, importantly, no indication of a confounding pre-trend when we aggregate the event dummies in other ways.

replace the *MML* treatment dummy from equation (1). τ_{ct} indexes these dummy variables such that when $\tau_{ct} = 0$ this denotes the period of the policy change. Period -1 is the reference period in all specifications. The end points are inclusive on the dummy variables such that they denote more than four semesters after and more than six semesters before the legalization became effective. Overall, the coefficients δ_j capture the impact on the outcome variable in treated states both prior to and after the treatment. They were estimated relative to the semester before the policy change, the omitted coefficient. The vector $\mathbf{X}_{cst}$ includes all control variables in our "preferred" specification described above. For the event studies we focus on the date the law is enacted rather than a specific law provision such as dispensaries becoming operative or home cultivation being allowed. We do this because the event study itself makes trends over time in the effects of laws explicit. If there are smaller increases in marijuana use directly after a law is enacted due solely to changes in enforcement, monitoring, or attitudes from enacting the law; then assigning treatment at a later date would cause these changes to be picked up as pre-trends in the model.

5. Results

5.1 MMLs and Marijuana use

We first document that MMLs increase marijuana use in our sample and time period. We use equation (1) to estimate the effect of MMLs on increasing the likelihood of marijuana use in the past 30 days, with results shown in Table 3. We use both definition of treatment: when MMLs became effective and the effective date for states where home cultivation is allowed. We find that compared to non-MML states, individuals living in states that changed medical marijuana laws are more likely to consume marijuana in the past 30 days. Estimates are consistent across specifications, including when we add individual fixed effects or focus on home cultivation. Overall, these results suggest around a 5.14 percentage points increase in the likelihood of consuming marijuana or an effect of roughly 33% of the mean. Results for states that passed home cultivation laws are consistent, although slightly larger in magnitude. Overall, these effects are larger but generally in line with the earlier literature. Wen et al. (2015) report a 14% increase in marijuana use for individuals aged 21 and above over the period 2004-2012. Focusing on non-medical population, Chu (2014) finds a 10-20% increase in marijuana related arrests and treatments, which jointly provides indirect evidence of increasing recreational use. However, our estimates are unique in that, unlike earlier papers, we look only at young adults between the ages of 21-30. We believe these results show that adults in this age are more responsive to recreational take up of marijuana in response to an MML law change than those who are older or younger.[27] Notably, teenagers are also less responsive to MMLs than adults, and we have replicated the earlier literature by Anderson et al. 2015 that MMLs do not affect teen use (results available upon request).

Figure 1 shows the event study in marijuana use. Before the law is passed, reported marijuana use has a flat pre-trend, with none of the pre-period coefficients being statistically different from zero. There is a relatively sharp increase in reported use in the period during which the law is passed. Marijuana use continues to increases in the following two years, consistent with the gradual spread of marijuana availability in the wake of the law. This is also consistent with their being a delay, in some states, between passing the law and enacting supply side measures such as making dispensaries operational.

5.2 MMLs, Fertility, and Sexual Behavior

Table 4 Panel A, shows the impact of MMLs on the fertility rate. Overall, we find consistent results across specifications. The first column shows results controlling for county and year-quarter fixed effects, state-specific time trends, and demographic covariates. We find that the enactment of any medical marijuana laws increases the birth rate by 0.40 or approximately 4 births per quarter for every 10,000 women of childbearing age. Adding controls for the unemployment or focusing on the passage of home cultivation laws generally yields slightly larger effects. Finally, including state level policies in our preferred and final specification does not substantially affect the results: suggesting that MMLs caused 5.3 additional births per 10,000 women if any law is enacted or 6 births in states that pass home cultivation law. Jointly these results show increased birthrates in medical marijuana legalizing states of around 3% of the mean.

These results provide evidence that marijuana use has a considerable, unintended, and positive effect on fertility. This is in-spite of the negative biological effects suggested by the

[27] Specifically, Pacula et al (2014) use the NLSY9 and find a 14.3% increase in marijuana use once different types of laws are controlled for. However, their sample includes teens, which as shown in Anderson et al. (2015), MMLs have little no effect on teen use, particularly when individual fixed effects are included. Likewise Wen et al. (2015) and Choi et al. (2018) find a smaller increase in marijuana use; however, these papers look at the population ages 12 and older and 18 and older respectively: rather than just those aged 21-30.

medical literature. Next, we attempt to understand this finding by looking at the underlying mechanisms. In other words: how does behavior change in a way that overcomes the biological impacts of the substance? First, we consider sexual frequency. Mechanically, the fertility rate will rise as more individuals engage in sexual activity, irrespective of contraceptive use. Panels B and C in Table 4 shows passage of MMLs is associated with increases in sexual activity. In accordance with the literature (e.g. Cavazos-Rehg et al., 2011; Heil et al., 2011; Tapert et al., 2001) we expect to find a stronger effect of MMLs on sexual frequency at the extensive margin (sex once or more in the past 30 days). Indeed, MMLs raise the probability of becoming sexually active in the past 30 days by as much as 6.9 percent over the mean rate. Results lose significance when focusing on "home cultivation", however are qualitatively similar with a t-statistic above 1, and we cannot rule out large positive effects on sexual activity in this specification[28]. Evidence at the margin of "3 or more acts of intercourse" also supports an increase in overall sexual activity; however, the effects are smaller and less precisely estimated.

The second way in which behavior could overcome the biological effect of marijuana is due to how it affects risky sexual behavior and contraceptive use. Conditional on sexual activity, the birth rate is expected to increase if individuals are less likely to actively prevent pregnancies through contraception. We account for this mechanism by investigating the impact of MMLs on self-reported condom use, and administrative data on condoms sales. Table 5, Panels A and B, report the estimates for the impact of MMLs on contraceptive use and sales, respectively. Consistent with the literature (e.g. George and Koob, 2010, Vangsness et al., 2005, Kingree and Phan, 2002) we find that the sign on the coefficient of MMLs on condom use is negative, suggestive of a decrease in condom use. However, this self-reported measure is noisy, and the results are statistically insignificant. This is likely due (in part) to sample sizes that are 6 time smaller than the rest of our NLSY outcomes.[29] Supplementing this result by using the retail sales data on condom sales we find that passage of an MML lowers condom sales by more than 4.3%.

It is important to note that the latter result indicate that MMLs lead to lower condom sales (and possibly use), but we are unable to comment with confidence whether this impact is clear

[28] One reason for loss of significance here is that when using this outcome from the NLSY97, unlike with the vital statistics, there are only four states that passed home cultivation laws: making statistical power a concern.
[29] As discussed in the empirical methodology section, state linear trends are excluded from the condom use regressions because small sample means it is likely that in including them we will be unable to reliably estimate both state trends over time and the effects of the laws. The results become very small, positive, and with standard errors that are 6 times as large as the point estimates, making it difficult to draw any conclusions in this case.

evidence of higher risky sexual activity. Thus, we also examine the impact of MMLs on other forms of sexual risky behavior, namely sexual activity with strangers. Panel C in Table 5 shows that MMLs have no impact on individuals' likelihood to have sex with someone unknown to the respondent. We have also estimated the effect of changes in MMLs on sexual transmitted diseases (STDs) using state-level data on chlamydia, syphilis, and gonorrhea available from the Centers for Disease Control and Prevention (CDC) finding no significant effect.[30] In light of the findings regarding risky sexual behaviors, we conclude that the impact of MMLs on the birth rate is primarily driven by higher frequency of non-risky sexual activity, and suggestively through lower use of contraceptives.

5.3 Fertility, and sex, event study results

We proceed to conduct an event study in order to formally test the validity of our findings on fertility and sexual activity. The event studies were estimated using equation (2) and all the covariates from our preferred specification. Figure 2 depicts the event study results of the impact of MMLs on the birth rate. There is generally no evidence of differential birth rate trends in the semesters prior to the passing of MMLs.[31] The figure then indicates a sustained increase in birth rate in the period following the policy change. Figure 3 shows our event study on the most prominent mechanism leading to an increase in birth rates: the probability of having sex once or more in the past 30 days. While there is a dip down in sexual activity two periods before the law passes, otherwise the pre-trends are fairly flat and not statistically different from zero. Further, Figure 3 shows an increase in sex beginning after the law change, with a small increase overtime as marijuana availability becomes more widespread.[32]

5.4 Law Heterogeneity

It is widely recognized in the MML literature that not all marijuana laws are the same. While, our main estimates make explicit differences in effects between any law being enacted and

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[30] Results are available upon request.
[31] For the event study analysis using the NLSY97 data we reduce the number of periods because of the fewer years of available data.
[32] Appendix Figure A1 also shows an event study in retail condom sales. The pattern is more difficult to clearly make out due to large confidence intervals relative to the effect size. Still, we were reassured not to see no distinct pre-trend in the pre-period followed by a relatively sharp decline following the passage of the law. We also did an event study on having sex "3 or more times" in the past 30 days. There was no evidence of a pre-trend and the pattern of coefficients was similar to our extensive margin measure of sex.

those that allowed for home cultivation, we recognize it is important to look at the full spectrum of laws. We focus this law heterogeneity analysis on fertility outcomes both because we see fertility as the end result of additional marijuana use and sex, and because the large sample size and longer panel of years available in the vital statistics makes it practical to horse race the effects of different laws.

Table 6 shows the results of different type of MMLs on the birth rate. The first column only defines treatment as laws that allow for home cultivation and is identical to the third column results in table 3. The second column assigns treatment based on when dispensaries in a state become operational and are actively supplying marijuana. The third column assigns treatment based only on states who pass laws that allow for "non-specific pain" for MML prescriptions. These states allow prescriptions to be given for generic "chronic pain" rather than a more specific condition, allowing a prescription to be more easily obtained. The final column horse races the relative effectiveness of these laws by including all of them in the same regression. Jointly, these three types of laws reflect the major ways in which the legal supply of marijuana could be most easily obtained.

Table 6 shows that the largest results on fertility comes from states that allow for home cultivation. Non-specific pain provision laws have reasonably sized effects, but are imprecisely estimated and not statistically significant. When these provisions are included separately in the same specification, home cultivation increases births by 4 births in a quarter per 10,000 women of child bearing age, and an operating dispensary increases births by 3 births per 10,000 women.

5.5 Quantifying the effects

We now put some prospective on the effect sizes in our estimates. The sexual activity results suggest that for adults aged 21-30, there is an increase in the likelihood of having sex once or more in the past month of around 4.5 percentage points. A rough back of the envelop calculation, implies that for every 10,000 women in this age group about 1350 more of them are likely to have intercourse in the past quarter[33]: in turn, resulting in 4 additional births within a quarter. This doesn't consider any intensive margin effects for those who would otherwise already be sexually active in a month. Further, the likelihood of a birth increases a great deal if

[33] A 4.5 percentage point increase per 10,000 women suggests 450 more having sex at least once per month, or 1350 per quarter.

contraception is not regularly used during intercourse. While our results on decreased condom use are largely suggestive: they imply a greater likelihood that our estimates of frequent intercourse will result in a pregnancy. Therefore, relative to our estimated increases in sexual activity, we consider 4 births per quarter a plausible increase in fertility. Another way to think about the magnitude of effects is to benchmark them against other policies or shocks that have changed fertility. We find effects on the fertility rate of 3% of the mean. Overall, these results are more modest then the impact of opening family planning clinics that reduced the fertility of poor mothers by 30% (Bailey, 2012) and similar to the estimated 2.6% decline in births due to increased temperatures from climate change (Barreca et al. 2015).

5.6 Further robustness and heterogeneity checks

We conduct a series of robustness checks to examine the sensitivity of the results. We test whether the effects from the legalization are realized before they should occur. This is done in two ways. First, by adding leads for the MMLs change to our preferred specification from Table 3. Panel A in Tables 7 and 8 shows the results from the robustness checks using sexual frequency and the general birth rate as outcome variables, respectively. The two columns add leads for 1 and 2 years before the policy, and thus control for a policy change at different times prior to MMLs becoming effective. The main treatment variable remains significant with a magnitude that is not substantially different from before while the coefficients for the leads are negative and statistically insignificant. These results indicate that the impact of the policy remains captured by the original treatment variable and it is not absorbed by leads.

Second, we check that the effects we find are not spurious by replacing the main policy variable with 1,000 sets of placebo dates for the change in MMLs. Specifically, using a uniform distribution we randomly generated 1,000 sets of fake dates from the first quarter of 2006 to one year before the actual effective date of the change in the laws. This allows us to have data on births at least one year before and after the change in MML laws. Data on births occurring from the true effective date were dropped from the sample to avoid contaminating the test with the truly treated period. Then, we estimated equation (1) 1,000 times where at each time the treatment indicator, MML_{st}, was defined according to the placebo dates. Summary statistics from the distribution of the placebo treatments are presented in Panel B of Tables 7 and 8. We find that these placebo dates do not capture any effect for the policy change. The estimated effects are small and statistically insignificant at any conventional level, and were positive and statistically significant at the 10 percent level only 65 times for sex frequency and 108 times for fertility out of 1,000 replications.

In appendix Table A-2 we also test for the sensitivity of the fertility results to using state instead of county fixed effect as well as the exclusion of linear trends. Notably, when we do not include state-linear trends the coefficient estimate is virtually identical to our preferred specification, though the standard errors are substantially larger. We interpret this as there being linear trends over time across in sex and fertility that are explained by linear trends that are not related to the laws but help substantially with provision. Regardless, after including county fixed effects, the coefficient on MMLs becomes very stable to the inclusion of additional covariates (as shown in Table 3). This reinforces that county fixed effects absorb some important heterogeneity and reinforces our decision to include those in our main specification.

Finally, we find evidence of heterogeneous effects of MMLs between different demographic groups. Table A-3 presents these results. As shown in Panel A, MMLs has a statistically and economically significant effect across groups identified by marital status. However, the impact of MMLs is more strongly observed among unmarried individuals, with the overall effect being 4.3% over the mean birth rate for this subgroup. Alternatively, of the 5.7 births from an MML for every 10,000 women, 3.7 of them are from unmarried mothers. However, this does not mean that these births are necessarily "unwanted" as the rate of out of wedlock births has been increasing in recent years suggesting that the "marginal birth" in the US is to an unmarried mother. Heterogeneous effects by racial group show that whites exhibit a stronger fertility response than blacks; with an increase of 4%. Hispanics exhibit a stronger response than non-Hispanics with an increase of 3.7%. Lastly, we can't rule out any differences across education groups, though the coefficient on MMLs for college educated mothers is negative (but imprecisely estimated).

6. Recreational Spillovers

Despite the fact that we focus on medical marijuana laws, which covers a very narrow segment of the population, we find that the related impacts on the overall population are rather large. This raises the issue of the extent to which marijuana that was originally authorized for medical purposes is spilling over to other segments of the population. To get a sense of this, we first calculate the population of our treated states and their number of medical marijuana patients in 2014. We choose 2014 as this is the last year of our sample and therefore represents a reasonable approximation of our post period. Using the treatment effect of 4 births per 10,000 women we calculate the number of additional births in these states from MMLs. Under the assumption that all of the births are due to the population of legal medical marijuana patients this would imply a treatment on the treated birth rate, which represents 76 births per 1,000 women. This is a rate that is 4.6 times larger than the general birth rate in the US population.[34] Put it in a different way, if all of these births are due to non-medical marijuana users who, somehow, were able to obtain cannabis from medical users we find that for every 100 medical marijuana users 7 individuals are able to both divert cannabis to non-medical use and pregnancy results. Therefore, it seems likely our results are largely driven by recreational use.

While early adopters, such as California, Colorado, Oregon, and Washington had relatively little monitoring of the supply and related mechanisms, late adopters put in more strict restrictions that, it was believed, left little room for potential spillovers to non-medical use (Anderson and Rees, 2014, 2014a). However, recent studies that also exploited variation in the laws for late adopters find evidence of significant spillover effects (Wen et al., 2015; Choi et al., 2018).[35] Our findings, do not appear to be spurious given their consistency across the board and in particular given the very strong evidence provided above that there are very significant first stage effects that parallel our fertility findings that show that marijuana laws do spill over to non-medical use, at least for the population of young adults in peak childbearing years. They are also consistent with findings in the medical literature. For instance, Hasin, et al (2017) show that illicit cannabis use increased significantly more in states that passed medical marijuana laws than in other states and that, in general, such laws have contributed to an increased prevalence of illicit cannabis use, which has also resulted in a dramatic increase in cannabis-related health disorders.

We argue that there are several mechanisms that further help explain the reason why spillovers occur even if the medical supply has become more tightly regulated for late adopting states. First, as tightly as laws are written, they are very difficult to enforce and monitor because cannabis is highly transportable, which undermines many of the restrictions local governments seek to impose on the distribution of the drug. Even if effective, the laws simply tend to displace

[34] We have a quarterly population of about 14 million people in our treated states, which in theory give birth almost 56,000 babies due to medical marijuana laws.
[35] Wen, et al. (2015) focus on the period 2004 to 2012 and Choi, et al, (2018) focus on the period 2002-2015.

activities onto more permissive jurisdictions nearby (Mikos, 2015, 2017). In fact, very recent research on recreational marijuana highlights the issue of transportability (Hansen, et al., 2018; Hao and Cowan, 2017).[36] A second reason that helps explain our findings is marijuana potency, which is consistent with our finding of increased sexual activity. As ElSohly et al., (2016) and Sevigny, et al., (2014) show, marijuana potency has risen dramatically over the past two decades. In particular, the latter find suggestive evidence that potency increased by a half percentage point on average after legalization of medical marijuana and that legal allowances for retail dispensaries had the strongest influence, significantly increasing potency by about one percentage point on average. Along the same lines, Freeman, et al., (2018) show that cannabis potency is correlated with the fact that the number of people entering specialist drug treatment for cannabis problems. In particular, in their 16-year observational study, they find positive links between changes in cannabis potency and first-time cannabis admissions to drug treatment. In addition to increased sexual activity, transportability, and potency, it is reasonable to expect that factors such as social acceptance of marijuana compounded by emboldened suppliers who tend to focus on the adult population (Anderson et al., 2015) as well as perceptions that penalties and related enforcement have become more lax for illegal possession by claiming medical use, and drastic price decrease of marijuana on the black market (Anderson et al, 2013.) may likely play a role, too.

7. Summary and Conclusions

There is widespread belief that the discoveries in the hard sciences are more credible than those in the soft sciences. In this paper we argue that several first order research questions are best addressed from an interdisciplinary perspective. We test this general idea by focusing on the causal link between consumption of marijuana and fertility rates, a question that stands in the intersection between the social and medical sciences. In fact, whereas this question has not been previously addressed in the former it is a question in which the physiological literature has reached some

[36] Hansen, et al. (2018) measure trafficking with a natural experiment on recreational marijuana and find that Washington retailers along the Oregon border experienced a 41 percent decline in sales immediately following Oregon's market opening. In counties that are the closest crossing point the estimated decrease was a staggering 58 percent. They also find suggestive evidence that inter-state spillovers lead to health externalities. Similarly, Hao and Cowan (2017) focus on the spillover effects of recreational marijuana legalization in Colorado and Washington on neighboring states and finds that it causes a sharp increase in possession arrests in border counties of neighboring states relative to non-border counties. They also show an increase in use in neighboring states relative to non-neighboring states.

consensus. This makes an interdisciplinary approach particularly relevant given the potential public policy implications.

We answer this question by exploiting the differences in timing in the introduction of medical marijuana laws among states, an uncontroversial methodological approach that has been used in several recent papers that study the impact of marijuana use on different outcomes, including domestic violence, alcohol consumption, traffic fatalities, and others. In fact, we believe that by using this approach we are also better able to study the main driving behavioral mechanisms that may cause cannabis use to increase fertility rates. We also believe that focusing on the unintended consequences of the legalization of medical marijuana is important in of itself for at least three reasons. First, medical marijuana is likely to be legalized by more states in the future. Unlike legalization of recreational marijuana, passage of MMLs is more likely to occur in states that do not necessarily have more liberal views towards drug use. Legalization of medical marijuana is a first, albeit important step toward the legalization for recreational use. Finally, given the potential extent of spillovers towards recreational use, the legalization for medical use has a quasi-legalization effect, which helps predict the impact of future adoption of recreational marijuana laws.[37]

Overall, we find evidence that behavior may overcome physiological mechanisms, as we find that the overall causal link between MMLS and fertility ends up being positive and economically significant. The stated physiological link in the medical literature that asserts a negative relationship is apparently dominated by positive behavioral changes in sexual activity. In other words, the consumption of cannabis may produce changes in behavior that surpass the hormonal changes detected in physiology to the extent that the overall impact on fertility may end up being positive, not negative.

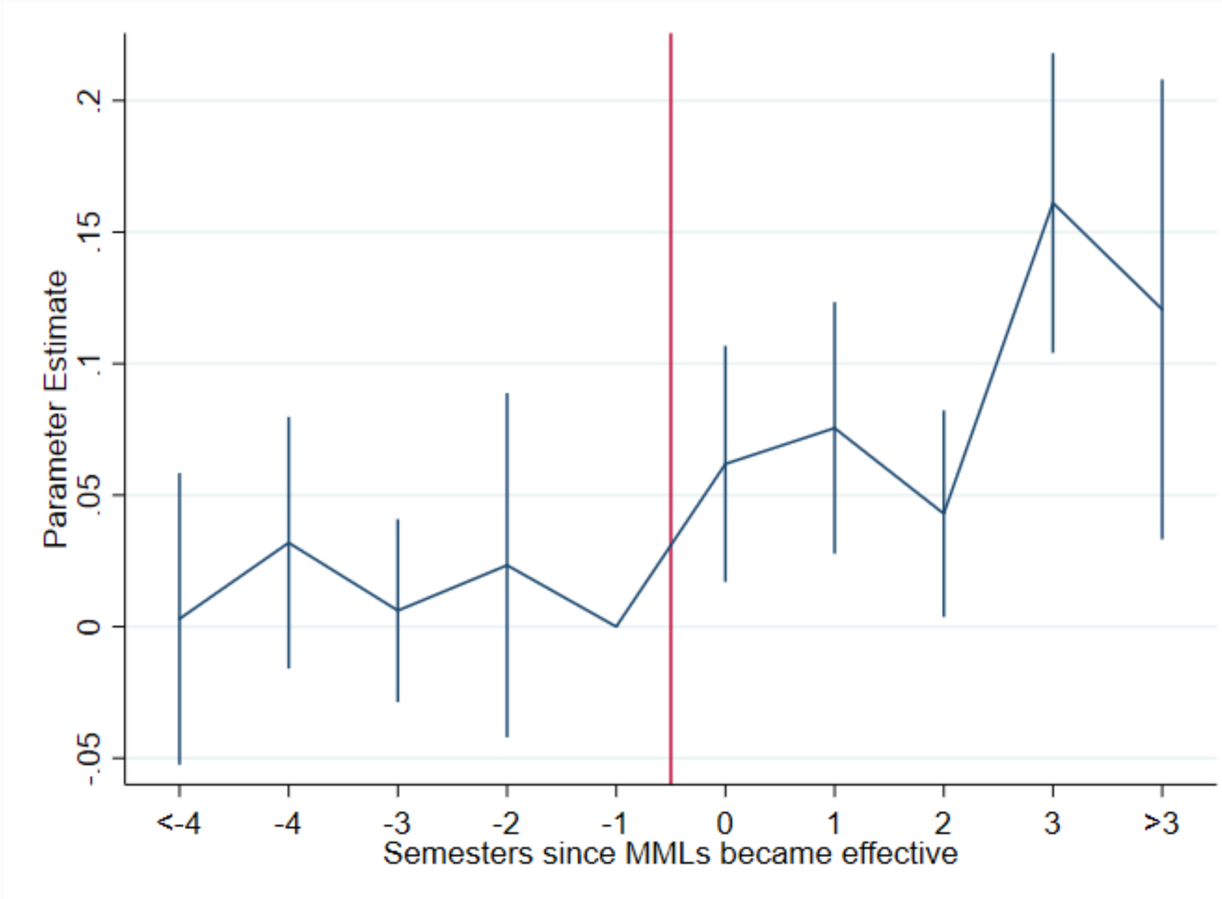
The behavioral mechanisms that drive our findings are mainly two. We find that increased intercourse and changes in perceived risk are both causal mechanisms that explain increased birth rates in the population. In particular, our results show increased birth rates coupled with a higher likelihood of having intercourse. We also find suggestive evidence that shows a decrease in condom use and retail condom sales, which may be due to behavioral responses such as increased

[37] It should be noted that to our knowledge there are no datasets containing information on both sex and drug use spanning across the adoption of recreational marijuana laws, which renders the study of medicinal use as particularly useful.

attention to immediate hedonic effects of sexual contact, delayed discounting and ignoring costs associated with risky sex. These findings are robust, as placebo, falsification tests, and event study analysis confirm our causal interpretation of our findings between cannabis, fertility rates and the main mechanisms identified.

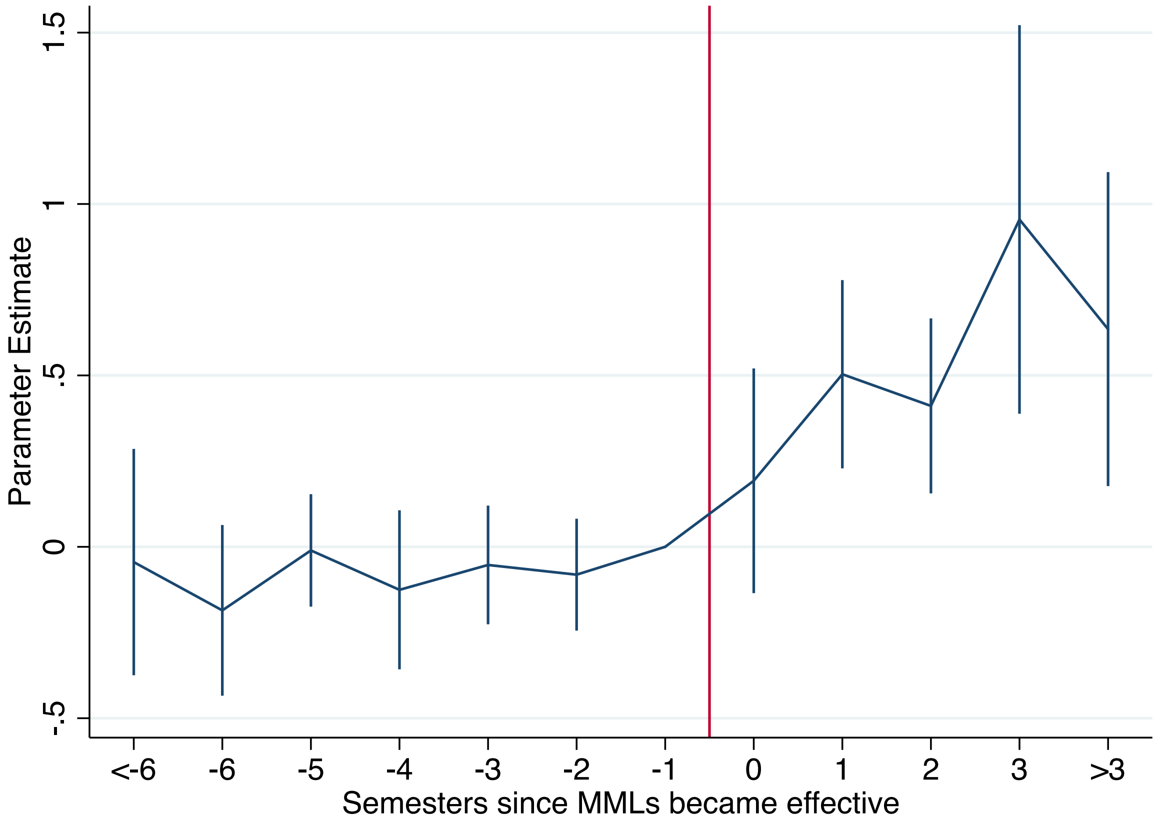
From a public policy perspective, we also raise some relevant issues. Our back-of-the-envelope calculations show that the increase in births due to spillovers to non-medical users is significant. Therefore, the public health implications are potentially large, particularly given the fact that spillovers may impact some groups more than others. This may mean that cannabis use results in increases on public health expenditures related to pregnancy, though this could be balanced out by beneficial increases to the population growth, which has been "below the replacement rate" in the United States and other developed countries. These effects may be compounded by the fact that recreational cannabis may be further legalized in additional States to the current ones. This finding brings to the fore not only the importance of better understanding the fertility-related magnitudes that the legalization of recreational marijuana may bring in the near future, but also other potential health-related negative (and positive) externalities derived from its use, including stress and mental health related impacts, which interestingly have not been well studied.

Figure 1 – Event Study. Having used marijuana in the past 4 weeks (2005-2011).



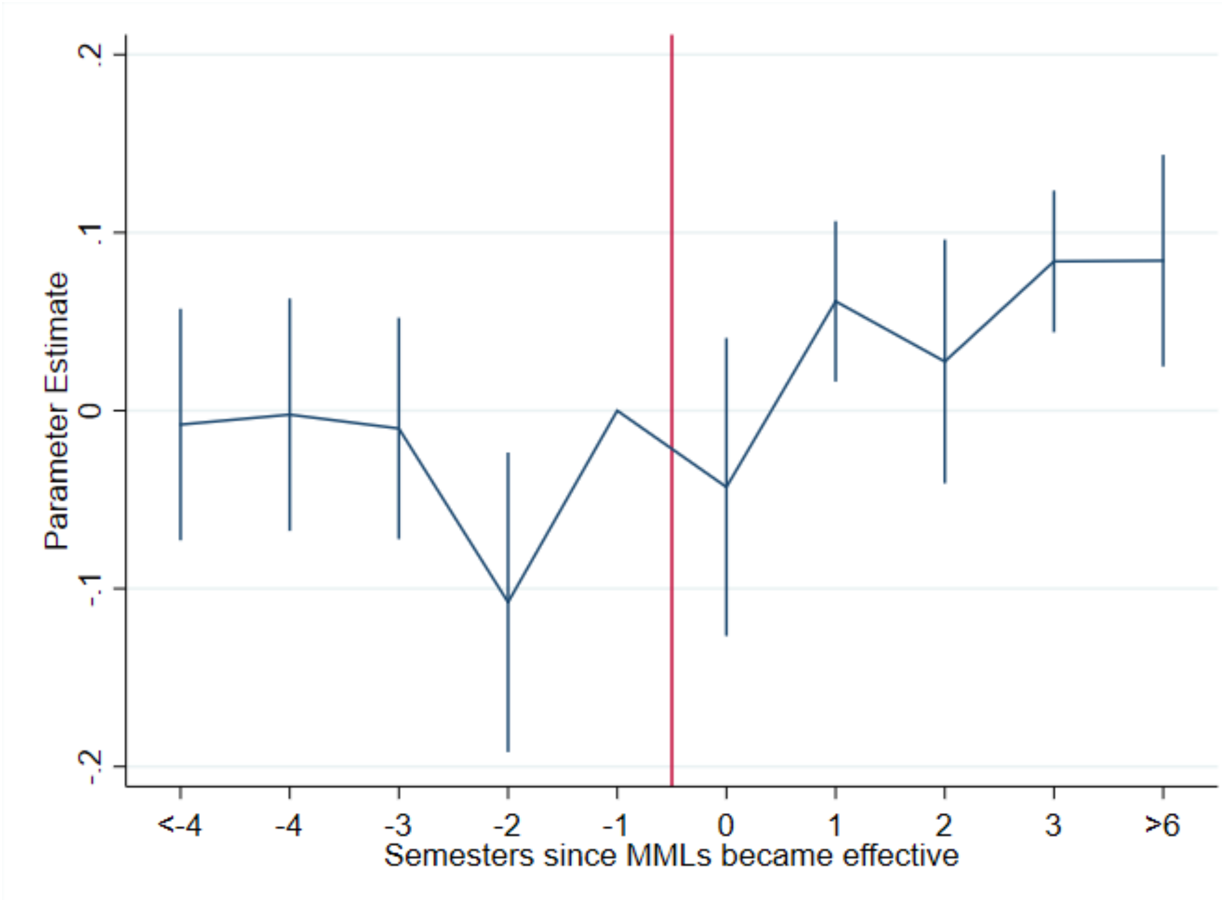
Notes: The graph shows parameter estimates and 95% confidence interval for semesters before and after the change in MMLs from a regression that controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Furthermore, each regression also controls for state and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. The regression also includes individual-level covariates on demographic and educational attainment of respondents. Regression is weighted using sample weights. Standard errors are clustered at the state level.

Figure 2 – Event Study. Fertility: General Birth Rate (2005-2014).



Notes: The graph shows parameter estimates and 95% confidence interval for quarters before and after the change in MMLs from a regression that controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Furthermore, each regression also controls for state and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regression is weighted by total county population. Standard errors are clustered at the state level.

Figure 3 – Event Study. Sexual frequency in the past 4 weeks: Had sex at least once (2005-2011).



Notes: The graph shows parameter estimates and 95% confidence interval for semesters before and after the change in MMLs from a regression that controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Each regression also includes individual-level covariates on demographic and educational attainment of respondents. Furthermore, each regression also controls for state and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regression is weighted by survey sampling weights. Standard errors are clustered at the state level.

Table 1 –Dates of Medical Marijuana Laws and Provisions, 2004-2014

State	Law becomes effective	Home cultivation	Open first Dispensary /treatment center	Legal Supply First Available in State	Non-specific pain
Arizona	April 14, 2011[a]	Yes	December 2012	April 14, 2011	Yes
Connecticut	October 1, 2012	No	August 20, 2014[b]	August 20, 2014	No
Delaware	July 1, 2011	No	--------------	--------------	Yes
D.C.	July 27, 2010	No	July 30, 2013	July 30, 2013	No
Illinois	January 1, 2014	No	--------------	--------------	No
Maine	--------------	-----	March 2011	--------------	---
Maryland	June 1, 2014	No	not operational	not operational	Yes
Massachusetts	January 1, 2013	Yes	--------------	Jan. 1, 2013	No
Michigan	December 4, 2008	Yes	--------------	Dec. 4, 2008	Yes
Minnesota	May 30, 2014	No	--------------	--------------	No
New Hampshire	July 23, 2013	No	--------------	--------------	Yes
New Jersey	October 1, 2010[a]	No	December 6, 2012	Dec. 6, 2012	Yes
New Mexico	July 1, 2007	Yes	June 2009[c]	July 1, 2007	No
New York	July 5, 2014	No	--------------	--------------	No
Oregon	--------------	----	March 2014	--------------	---
Rhode Island	January 3, 2006	Yes	April 19, 2013	January 3, 2006	Yes
Vermont	July 1, 2004	Yes	June 2013	July 1, 2004	Yes[d]

Notes: Home cultivation and Non-specific pain provisions become effective when the law becomes effective, unless otherwise stated. The "First supply" date is the date legal supply of marijuana becomes available in the state and is assigned as either the first date of home cultivation or the first date that a dispensary becomes open and active. Sometimes an MML first becomes enacted outside of our sample period even though it later passes a provision that occurs within our sample timeline. In these cases, we mark the date or provision as "--------", since we do not use this variation in our analysis. Dates for all Medical Marijuana Laws (MMLs) and provisions are gathered from the Marijuana Policy Project (MPP): "State-by-State Medical Marijuana Laws Report and Medical Marijuana Program Implementation Timelines". Because of discrepancies between MPP and existing literature we rely on effective dates published in previous MMLs papers or other sources: [a] Sabia et al (2017); Anderson et al (2013 and 2015); [b] Wen et al (2015). [c] DEA Position on Marijuana, US Dept. of Justice, July 2010; accessed September 2018 [d] Wen et al. (2015) reports 2007/07, so we assigned the law from this date. See the references for web hyperlinks.

Table 2 – Descriptive Statistics for Outcome Variables from Vital Statistics (2005-2014), NLSY97 (2005-2011), and Condom Sales (2006-2014).

Panel A: Vital Statistics, Fertility Rates (per 1000 women of child bearing age)	**N. Obs.**	**Mean**	**Std.**
General	122,415	14.83	8.76
Married	122,415	8.84	5.64
Unmarried	122,415	6.00	3.89
White	122,415	15.19	9.51
Black	122,415	14.74	12.79
Hispanic	122,415	19.56	17.08
Not Hispanic	122,415	13.72	8.33
Panel B: NLSY97			
Using Marijuana in the last 30 days	40,708	0.1499	0.3594
Had sex more than once in the last 4 weeks	38,193	0.6574	0.4746
Had sex more than three times in the last 4 weeks	38,193	0.5339	0.4989
Percentage of condom use since last interview	5,336	36.944	43.378
Sex with stranger since last interview	40,651	0.0556	0.2292
Panel C: Nielsen Scanner Data, Condom Sales			
County-quarter sales	84,732	$215,110.5	$392,465.9

Notes: All means are weighted by sampling weights for the NLSY97 data and total county population for condom sales and vital statistics. All the monetary data are in 2015 dollars. Fertility rates are based on number of women of child bearing age (18-44) in a county/quarter. We do not have county level population counts by marital status and age. Therefore, for marital status subgroup specific fertility rates we use total (female child bearing) population in the denominator. Hence, these rates are mechanistically lower than the general fertility rate.

Table 3 – Medical Marijuana Laws on Marijuana Use (2005-2011).

	(1)	(2)	(3)	(4)
Using in the past 30 days				
Any MML Effective	0.0501**	0.0544**	0.0629***	0.0512**
	(0.0198)	(0.0232)	(0.0196)	(0.0239)
Home cultivation	0.0605**	0.0684*	0.0778***	0.0650**
	(0.0277)	(0.0346)	(0.0269)	(0.0296)
Observations	40,693	40,693	40,693	40,693
Mean	0.15			
Demographic Controls	YES	YES	YES	YES
Unemployment Rate	NO	YES	YES	YES
State Policies	NO	NO	YES	YES
Individual FEs	NO	NO	NO	YES

Notes: *** p<0.01, ** p<0.05, * p<0.1. *First enacted* denotes the date the law became effective. *Home cultivation* denotes the effective date for states where home cultivation is allowed. Each regression includes county and year-quarter FEs, state-specific time trend, and controls for decriminalization and legalization of recreational marijuana consumption. *Demographic Controls*: share of total county population by race, heritage, age, and educational achievement. *Unemployment Rate*: unemployment rate together with the interactions between demographic variables unemployment rate. *State Policies*: state cigarette and beer tax, Medicaid expansion and abortion laws, and all interactions between each of the demographic and educational covariates. Regressions are weighted using sample weights. Standard errors in all regressions are clustered at the state level.

Table 4 --Medical Marijuana Laws on Fertility (2005-2014) and Sexual Behavior (2005-2011).

	(1)	(2)	(3)	(4)
Panel A: Fertility rate				
Any MML Effective	0.403**	0.490***	0.537***	
	(0.133)	(0.125)	(0.102)	
Home cultivation	0.396***	0.513***	0.603***	
	(0.102)	(0.138)	(0.132)	
Observations	122,415	122,415	122,415	
Mean	14.83			
Panel B: Had sex at least once				
Any MML Effective	0.0318	0.0451**	0.0412**	0.0428**
	(0.0233)	(0.0207)	(0.0175)	(0.0211)
Home cultivation	0.0102	0.0282	0.0305	0.0300
	(0.0158)	(0.0214)	(0.0219)	(0.0203)
Mean	0.657			
Panel C: Had sex at least three times				
Any MML Effective	0.0208	0.0244*	0.0225*	0.0240
	(0.0131)	(0.0127)	(0.0121)	(0.0186)
Home cultivation	0.0150	0.0187	0.0221	0.0252
	(0.0139)	(0.0161)	(0.0161)	(0.0225)
Observations	38,179	38,179	38,179	38,179
Mean	0.534			
Demographic Controls	YES	YES	YES	YES
Unemployment Rate	NO	YES	YES	YES
State Policies	NO	NO	YES	YES
Individual FEs	NO	NO	NO	YES

Notes: *** p<0.01, ** p<0.05, * p<0.1. *First enacted* denotes the date the law became effective. *Home cultivation* denotes the effective date for states where home cultivation is allowed. Each regression includes county and year-quarter FEs, state-specific time trend, and controls for decriminalization and legalization of recreational marijuana consumption. *Panel A*: regressions are weighted by total population of the county by year. *Panel B and C*: each regression also includes individual-level covariates on demographic and educational attainment of respondents and is weighted using sample weights. Standard errors in all regressions are clustered at the state level.

Table 5 – Medical Marijuana Laws on Risky Sex.

	(1)	(2)	(3)
Panel A: Condom Use since previous interview			
Any MML Effective	0.00124	-0.00552	-0.00971
	(0.0213)	(0.0265)	(0.0419)
Observations	5,334	5,334	5,334
Mean	0.369		
Panel B: Condom Sales			
Any MML Effective	-0.0398*	-0.0443**	-0.0363**
	(0.0202)	(0.0196)	(0.0169)
Observations	84,732	84,732	84,732
Mean	10.73		
Panel C: Sex with Strangers since previous interview			
Any MML Effective	0.00538	0.00314	0.00768
	(0.0188)	(0.0203)	(0.0220)
Observations	40,636	40,636	40,636
Mean	0.0556		
Demographic Controls	YES	YES	YES
Unemployment Rate	NO	YES	YES
State Policies	NO	NO	YES

Notes: *** p<0.01, ** p<0.05, * p<0.1. *First enacted* denotes the date the law became effective. Each regression includes county and year-quarter FEs, state-specific time trend, and controls for decriminalization and legalization of recreational marijuana consumption. *Demographic Controls*: share of total county population by race, heritage, age, and educational achievement. *Unemployment Rate*: unemployment rate together with the interactions between demographic variables unemployment rate. *State Policies*: state cigarette and beer tax, and abortion laws, and all interactions between each of the demographic and educational covariates. State linear time trends are dropped from the condom use regressions due to the extremely small sample sizes. *Panel A* and *C*: each regression also includes individual-level covariates on demographic and educational attainment of respondents. Regressions are weighted using sample weights. *Panel B*: regressions are weighted by total population of the county by year. Standard errors in all regressions are clustered at the state level.

Table 6 – Policy Heterogeneity in Medical Marijuana Laws on Fertility Rate (005-2014).

	(1)	(2)	(3)	(4)
Home cultivation	0.603***			0.415*
	(0.132)			(0.211)
Dispensary Open		0.314**		0.308**
		(0.137)		(0.136)
Non-specific pain			0.507	0.285
Provision			(0.156)	(0.196)

Notes: *** p<0.01, ** p<0.05, * p<0.1. Each regression includes county and year-quarter FEs, state-specific time trend, and controls for decriminalization and legalization of recreational marijuana consumption. The title of each column denotes the specific included in the regression. In all specifications we include the full set of demographic and state policy controls.

Table 7 – Robustness Checks for Sexual Frequency, *Had sex at least once*: Time Indicators / Policy Reassignment.

	(1)	(2)
Panel A: Time Indicators		
Any MML Effective	0.0487**	0.0407**
	(0.0146)	(0.0193)
1 year before	0.0146	
	(0.0204)	
2 years before		-0.0034
		(0.0211)
Observations	38,179	38,179
Panel B: Policy Reassignment, placebo dates		
Average placebo MML estimate	-0.0059	
	(0.0300)	
Placebo coefficient > 0	416	
Placebo coefficient > 0 and significant at 5% level	46	
Placebo coefficient > 0 and significant at 10% level	65	
Observations	36,775	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Each regression controls for all covariates: demographic controls, unemployment rate and interactions, state policies and interactions, as well as individual-level covariates, state, and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regressions are weighted using sample weights. Standard errors in all regressions are clustered at the state level.

Table 8 – Robustness Checks for *General Fertility Rate*: Time Indicators / Policy Reassignment.

	(1)	(2)
Panel A: Time Indicators		
Any MML Effective	0.525***	0.4536***
	(0.098)	(0.101)
1 year before	-0.105	
	(0.072)	
3 years before		0.045
		(0.089)
Observations	122,415	122,415
Panel B: Policy Reassignment, placebo dates		
Average placebo MML estimate	0.0259	
	(0.1073)	
Placebo coefficient > 0	588	
Placebo coefficient > 0 and significant at 5% level	72	
Placebo coefficient > 0 and significant at 10% level	108	
Observations	118,073	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Each regression controls for all covariates: demographic controls, unemployment rate and interactions, state policies and interactions, as well as state and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regressions are weighted using sample weights. Standard errors in all regressions are clustered at the state level. Regressions are weighted by total population of the county by year. Standard errors in all regressions are clustered at the state level.

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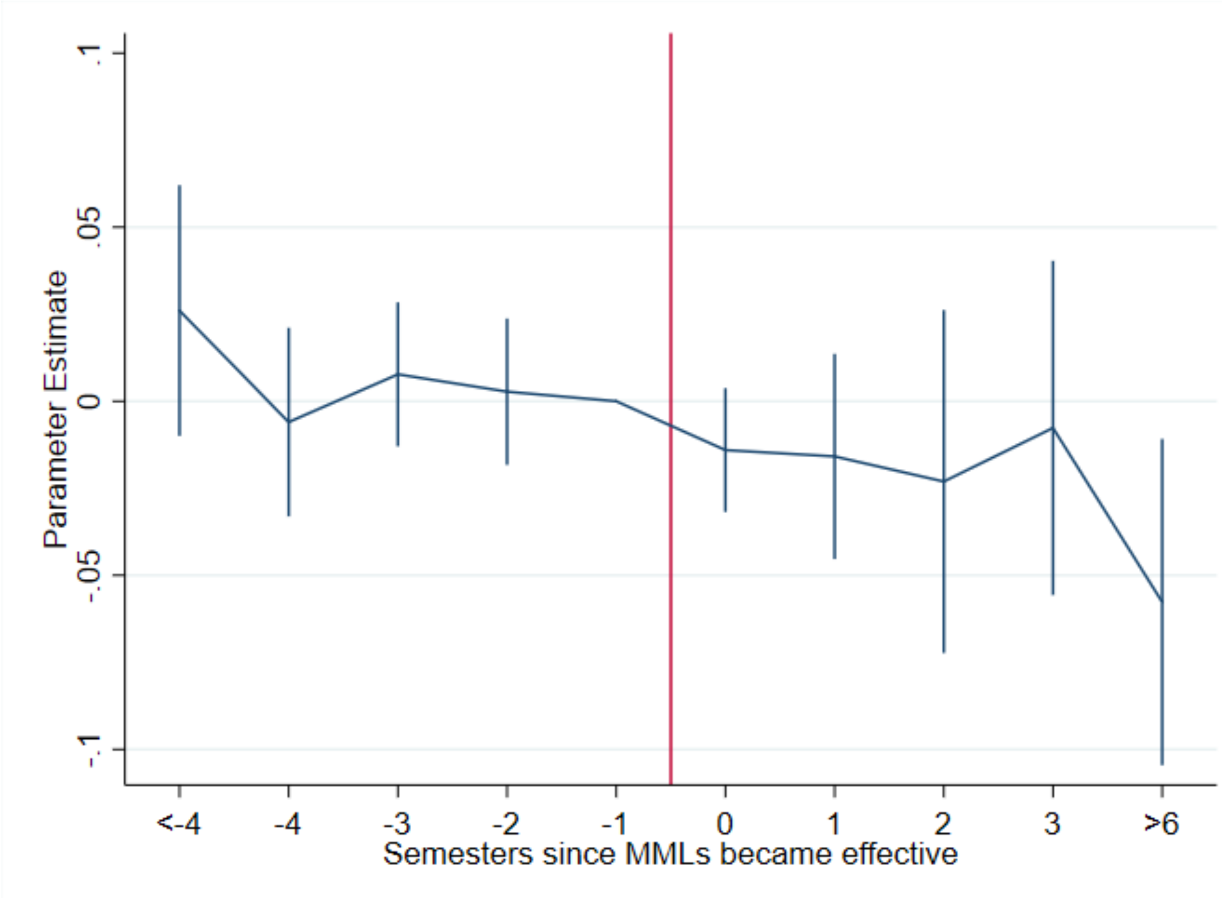
Appendix Figures

Figure A1 – Event Study: Condom Sales (2006-2014).



Notes: The graph shows parameter estimates and 95% confidence interval for quarters before and after the change in MMLs from a regression that controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Furthermore, each regression also controls for state and year-quarter fixed effects, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regression is weighted by total county population. Standard errors are clustered at the state level.

Table A1 – Descriptive Statistics for Covariates

	N. Obs.	Mean	Std.
Panel A: individual-level covariates NLSY (2005-2011)			
Black	40,828	0.157	0.364
Male	40,828	0.513	0.499
Dropout	40,828	0.083	0.277
High school	40,828	0.581	0.493
Higher education	40,828	0.329	0.469
Panel B: county-level covariates			
Total population	31,402	1,100,279	1,904,628
% Male	31,402	0.492	0.012
% White	31,402	0.795	0.149
% Black	31,402	0.136	0.133
% Asian	31,402	0.055	0.074
% Other	31,402	0.013	0.035
% Hispanic	31,402	0.161	0.165
% Population 0-19 years old	31,402	0.269	0.031
% Population 20-39 years old	31,402	0.270	0.041
% Population 40-64 years old	31,402	0.329	0.029
% Population 65- years old	31,402	0.132	0.036
Unemployment rate	31,402	7.007	2.700
Median income	31,402	$57,323.86	$15,085.28
Panel C: state-level covariates			
% Dropout	510	0.119	0.029
% High school	510	0.308	0.051
% Some college	510	0.284	0.032
% College	510	0.288	0.051
Decriminalized	510	0.352	0.477
Legalized	510	0.007	0.085
Cigarette tax	510	1.249	0.876
Beer tax	510	0.267	0.222
Medicare expansion	510	0.063	0.243
TRAP AFL	510	0.086	0.281
TRAP HR	510	0.220	0.414
TRAP ASC	510	0.047	0.212

Notes: Weighted by total county population. Individual level covariates are from the NLSY97 and are weighted by sampling weights. All the monetary data are in 2015 dollars.

Table A2 – Fertility Results: Sensitivity to Different Fixed Effect (FE) Specifications.

	(1)	(2)	(3)
Any MML Effective	0.562	0.746***	0.537***
	(0.420)	(0.221)	(0.102)
Observations	122,415	122,415	122,415
Birth Rate (mean)	14.83		
State FE	YES	YES	NO
State linear Trends	NO	YES	YES
County FE	NO	NO	YES

Notes: *** p<0.01, ** p<0.05, * p<0.1. Outcome variable is general birth rate. Each regression controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Furthermore, each regression also controls for decriminalization and legalization of recreational marijuana consumption. The title of each column denotes the specific controls that are added to the regression. Regressions are weighted by total population of the county by year. Standard errors are clustered at the state level.

Table A3 – Heterogeneity. Subgroup-Specific Fertility Rates.

Panel A: Marital Status	**Whole Population**	**Unmarried**	**Married**	
MML=1	0.537***	0.370**	0.167*	
	(0.102)	(0.086)	(0.101)	
Observations	122,415	122,415	122,415	
Birth Rate (mean)	14.83	5.99	8.84	
Panel B: Race/Ethnicity	**White**	**Black**	**Hispanic**	**Not Hispanic**
MML=1	0.640***	0.352	0.717**	0.317**
	(0.114)	(0.346)	(0.260)	(0.127)
Observations	122,415	122,415	122,415	122,415
Birth Rate (mean)	15.19	14.74	19.56	13.72
Panel C: Education	**High School Dropouts**	**High School**	**Some College**	**College**
MML=1	0.272	0.288	0.149	-0.342
	(0.184)	(0.278)	(0.299)	(0.369)
Observations	122,415	122,415	122,415	122,415
Birth Rate (mean)	2.60	3.64	3.68	3.73

Notes: *** p<0.01, ** p<0.05, * p<0.1. Each regression controls for all covariates: share of total county population by race, heritage, age, and educational achievement, unemployment rate together with the interactions between demographic variables and unemployment rate, state cigarette, beer tax, Medicaid expansion and abortion laws, as well as all interactions between each of the demographic and educational covariates. Furthermore, each regression also controls for state and year-quarter FEs, state-specific time trend, and for decriminalization and legalization of recreational marijuana consumption. Regressions are weighted by total population of the county by year. Standard errors are clustered at the state level.