

# High on Innovation: The Impact of Liberalization Policies on Innovation

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## Abstract

This paper investigates the impact of liberalization policies on innovation. In particular, we measure the impact of two liberalization policies (legalization of medicinal marijuana and legalization of same-sex civil unions and domestic partnerships) and one anti-liberalization policy (passage of abortion restrictions) on patenting rate. Our empirical strategy exploits the staggered timing of legalization policies across different states in the United States. Our findings show that after controlling for state-level R&D and education-specific expenditures, liberalization policies increased patenting by 10% to 16% at the state level. In contrast, we find that the passage of an extra abortion restriction decrease patenting by 2%. In our exploration of the underlying mechanisms, we find a positive association between the enactment of liberalization policies and the inter-state migration of talent. Even after excluding mobile inventors, we still find that liberalization policies are associated with an increase in the patenting rate of existing residents. Our results suggest that liberalization policies increase regional innovation by potentially attracting creative types from other regions as well as facilitating higher levels of innovation among the existing residents. We discuss implications for regional and organizational policies.

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# 1 Introduction

There are considerable differences in productivity across regions (Jacobs, 1961; Agrawal, Cockburn, Galasso, and Ottel, 2014; Carolino and Kerr, 2014). To explain these disparities, scholars have attempted to identify various factors and policies that enhance regional creativity and innovation. Among others, a series of studies have contended that tolerance and openness to diversity plays an important role in fostering regional creativity and innovation (Jacobs, 1961; Florida, 2002a,b,c; Florida, Mellander, and Stolarick, 2008; Wedemeier, 2014). These studies suggest that regions with higher levels of tolerance and diversity are likely to be more successful in attracting creative individuals (Jacobs, 1961; Florida, 2002b; Florida, Mellander, and Stolarick, 2008), boost self-expression, and engage a more diverse population (Bowen and Blackmon, 2003; Page, 2007a) in creative activities. These arguments suggest that enacting more liberal policies in a region can enhance its creativity and innovative performance (Florida, 2002c; Inglehart and Welzel, 2005; Page, 2007b).

Despite the popularity of these claims among scholars and policy makers, there remains little empirical evidence for the causal impact of liberalization policies on innovation. The main empirical challenge is that differences in innovative outcomes after the implementation of a liberalization policy may be attributed to other unobservable factors that drive both changes in innovative outcomes as well as the implementation of policies. For instance, we may be concerned that differences in innovative output across states is attributed to differences in R&D spending or the fraction of educated employees (Glaeser, 2005), which have also triggered the implementation of these policies. Second, we may be concerned about reverse causality where the implementation of these policies are triggered by changes in innovative outcomes.

Our empirical strategy exploits the staggered timing of three different policies across different states in the United States. In particular, we examine the effect of two liberalization policies - the legalization of medicinal marijuana and legalization of same-sex civil unions and domestic partnerships, and one anti-liberalization policy - the passing of abortion restrictions - on the number patents per state. Our identification strategy relies on comparing the changes

in patenting of states that have experienced a policy change in a particular year relative to other states with no policy change in that year. Our baseline estimates control for state fixed effects and year fixed effects. State fixed effects control for all time-invariant differences across states, such as culture or geography. Year fixed effects control for all time-varying factors that affect states similarly, such as macroeconomic changes in the United States during this period. To further control for potential simultaneous state-specific changes, all estimates include yearly state-level total expenditure, share of education expenditure, and business R&D expenditure. We construct a large dataset on patenting (between 1994 and 2006) by each of the fifty states and the District of Columbia. In total, 13 states legalized medicinal marijuana between 1996 and 2006, and 10 states and the District of Columbia legalized same-sex civil unions or domestic partnerships between 1998 and 2006. Moreover, during the period of our analysis 34 states have passed new restrictions on abortions at different points in time.

Our results suggest that the legalization of medicinal marijuana increases patenting by about 16%. Similarly, the findings show that legalization of same-sex civil unions and domestic partnerships raises patenting rate by roughly 10%. In contrast, we find that passing of an additional abortion restriction reduces patenting rate by 2%. A 1% increase (decrease) in patenting rate per year roughly translates to about 21 additional (fewer) patents per year. Our results are robust to alternative specifications. Moreover, yearly treatment estimates do not suggest evidence of pre-trends in the periods leading up to the enactment of the liberalization policies. Our falsification tests further validate our findings.

In order to shed light on the underlying mechanisms, we run a series of analyses. First, we show that there is an increase in the absolute number of inventors after both liberalization policies whereas there is a decrease in the number of inventors after the passing of additional abortion restrictions. Second, we show a positive association between the two liberalization policies and the net-migration of skilled labor to a state (proxied by professional service workers and individuals with at least a bachelor's degree). In contrast, the passing of additional abortion restrictions is negatively correlated to the net migration of

skilled labor. These findings suggest that part of the change in patenting may be explained by the inter-state mobility of talent. Third, we explore whether liberalization policies facilitate regional innovation beyond attracting talent across states. We restrict the sample to non-mobile inventors and still find a significant increase in patenting after the legalization of medicinal marijuana and same-sex civil unions. This suggests that liberalization policies can also increase the output of existing inventors. Lastly, we do not find evidence that increases in marijuana consumption is correlated with an increase in patenting. Taken together, our results tentatively suggest that the increase in innovation is not just driven by the inflow of creative types from less liberal regions, but also by facilitating creativity of the existing population.

Our study contributes to the vibrant literature that has examined factors that facilitate regional innovation, such as industry agglomeration (Jacobs, 1969), skilled labor (Glaeser, 1999; Glaeser, Kolko, and Saiz, 2001; Shapiro, 2006), and infrastructure (Baum-Snow, 2007; Duranton and Turner, 2012; Agrawal, Galasso, and Ottel, 2014). We provide one of the first empirical evidences to suggest that more liberal environments have a significant and positive effect on regional innovation. More broadly, we also provide one of the first empirical studies on the impact of liberalization policies on innovation. These findings have implications for organizations and regional policy.

The next section overviews related literature. Section 3 describes each policy and timing of enactment across different states. Section 4 and Section 5 describe the data and empirical framework, respectively. Section 6 presents the results and Section 7 offers concluding remarks.

## 2 Related Literature

A substantial body of research has examined the factors that contribute to the disparity in innovative outcomes across geographical regions. The literature going as far back as Marshall (1890) highlights the role of regional agglomeration of business activities and human capital in facilitating local knowledge flows and knowledge accumulation within a region. In

her seminal book, Jacobs (1969) argues dense urban concentrations facilitate the flow and creation of ideas, which underpin economic growth. Several empirical works have established the local concentration of knowledge flows by illustrating the positive association between urban density, human capital and idea generation (Lucas, 1988; Glaeser, 1999; Glaeser and Mare, 2001; Glaeser, Kolko, and Saiz, 2001).

The primary argument behind the human capital story for regional innovation is that regional differences in productivity are largely driven by people. In particular, the presence of highly skilled people (usually measured as the percent of adults with a bachelor's degree) in metropolitan areas may increase new idea production and region-specific productivity levels (e.g., Glaeser and Saiz, 2004) by facilitating more frequent human interactions and intellectual spillovers. Glaeser, Kolko, and Saiz (2001) also argue that skills predict growth because skilled neighbors are an attractive consumption amenity. The policy prescription from this stream of research suggests that investing in education can facilitate human capital accumulation, and consequently regional innovation.

A relatively more recent line of research, pioneered by Richard Florida, argues that regions with more tolerant and liberal environments can engage a larger set of talented individuals in creative activities through at least two separate channels. First, it suggests that tolerant environments (typically measured by the presence of bohemians) are more attractive to talented and creative people and hence are more successful in attracting and retaining them (Florida, 2002c; Florida, Mellander, and Stolarick, 2008). The flow of talent to an area would then attract more talent and this virtuous cycle can eventually lead to higher concentrations of talent and creativity in some regions and lower concentrations in others (Stolarick and Florida, 2006). Second, it argues that more tolerant and liberal regions can make local resources more productive by engaging a more diverse population into creative activities (Jacobs, 1969; Florida, 2002a,b). For instance, Stolarick and Florida (2006) and Florida, Mellander, and Stolarick (2008) claim that the networks generated by the interaction between bohemians and the traditional technology community accelerate human capital externalities and knowledge spillovers.

One of the primary mechanisms through which diversity is argued to impact performance is that it brings together a wider range of knowledge, expertise and perspectives than a homogeneous group (Hoffman and Maier, 1961; Lazear, 1999; Jeppesen and Lakhani, 2010; Audretsch, Dohse, and Niebuhr, 2010), which in turn enhance creativity. Theoretically, Hong and Page (2004) demonstrate that a diverse team of randomly selected agents outperform a more homogeneous team of best-performing agents in terms of problem-solving. Using an experimental method, Jeppesen and Lakhani (2010) find that technical and social marginality is positively associated with more success in problem solving by bringing different perspectives and heuristics. The positive relationship between team diversity and performance has been empirically demonstrated for a range of diversity dimensions including ethnic (Kerr and Lincoln, 2010; Audretsch, Dohse, and Niebuhr, 2010; Parrotta, Pozzoli, and Pytlikova, 2012), gender (Cedric, 2009; Hoogendoorn, Oosterbeek, and van Praag, 2013; Hansen, Qwan, and Pan, 2013) and cultural (Ottaviano and Peri, 2006) diversity.

While these ideas have received considerable attention and have entered into the policy arena<sup>1</sup>, they have also received significant criticism. Some of these critiques surround the ambiguity of the concepts and measures introduced by Florida and his colleagues such as “creative class”, “Bohemian Index”, “Gay Index”, and “Diversity Index” (e.g. Markusen, 2006). The more prominent critique is the endogeneity concerns surrounding the estimated empirical relationship between creative outcomes and Florida’s measures of tolerance. For example, in his review of Florida’s *“The Rise of the Creative Class”*, Glaeser (2005) uses Florida and Knudson (2004)’s data to show that the estimated effect of bohemians in a metropolitan area on growth is economically and/or statistically insignificant after controlling for the fraction of educated adults.

In the face of these concerns, the impact of liberalization on innovation remains an

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<sup>1</sup>For example, the mayor of Denver bought and distributed multiple copies of the book to his senior staff, while initiating a strategy to rebrand the city as a creative center (Boston Globe, 2004). The Governor of Michigan launched a ‘Cool Cities’ program across the state in order to attract and retain those ‘urban pioneers and young knowledge workers who are a driving force for economic development and growth’ (Labor and Growth, 2004). Research recently conducted by Michigan’s Department of Civil Rights suggests that “People are leaving the state ... and seeking out jobs with employers that have policies and environments inclusive of and favorable toward LGBT employee” (Michigan Department of Civil Rights, 2013).

open question. This paper attempts to address this question by exploring the impact of two different liberalization policies and one anti-liberalization policy on state-level patenting rates. In addition, we take a step towards disentangling the two potential mechanisms (i.e. attracting talent from other regions and increasing the creativity of current residents) that drive regional creativity. To the extent that the relative increase in the patenting rate of states with more liberal policies is driven solely by inventions by talent attracted from other locations, one can argue that the increase in these states' creative outputs is coming directly at the expense of other states' human capital. On the other hand, if the increase in creative output is in part driven by an increase in the creativity of current residents, the net impact of implementing liberalization policies across all regions may be non-negative.

### **3 Background**

This section provides institutional details surrounding the two liberalization policies - legalization of medicinal marijuana and legalization of same-sex civil unions - and one anti-liberalization policy - passing of abortion restrictions.

#### **3.1 Medicinal Marijuana Legalization (MML)**

Legalization of medicinal marijuana is broadly linked to liberal policies and agendas in the United States and other countries (Haines-Saah, Moffat, Jenkins, and Johnson, 2014; Robinson and Fleishman, 1984). Under the Controlled Substances Act of 1970, cannabis, or marijuana, is classified as a Schedule 1 drug, having high potential for abuse, no medical use, and not safe to use without medical supervision. While the study of medicinal cannabis is difficult in the U.S. because of its Schedule 1 classification, cannabis has shown to exhibit some beneficial effects on a variety of diseases, although many studies are inconclusive and suffer from sample size concerns.<sup>2</sup>

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<sup>2</sup>The Institute of Medicine, run by the U.S. National Academy of Sciences, conducted a study in 1999 assessing the potential health benefits of cannabis and concluded that cannabis can mitigate nausea, appetite loss, pain and anxiety. See Joy and Watson (1999) for the study.

Starting in the late 1970s, several U.S. based advocacy groups attempted to change the drug policy and to decriminalize cannabis. For instance, the Connecticut Law Revision Commission recommended that Connecticut reduces cannabis possession of one ounce or less for adults aged 21 years and over to a civil fine. In 2001, the New Mexico state-commissioned Drug Policy Advisory Group stated that decriminalizing cannabis “will result in greater availability of resources to respond to more serious crimes without any increased risks to public safety.” In 2005, over 500 economists, including libertarian economist Jeffrey Alan Miron and Nobel Laureate Milton Friedman, called for legalizing cannabis in an open letter to George W. Bush. They argued that replacing prohibition with a system of taxation and regulation could save \$7.7 billion per year in state and federal expenditures on enforcement and generate as much as \$6.2 billion in tax revenue annually if marijuana were taxed similarly to alcohol or tobacco.<sup>3</sup>

Medical marijuana legalization (MML) policies vary across states. During our sample period of 1996 to 2008, thirteen states legalized medicinal marijuana (Table A1). They have received considerable media attention at the local and national level, in part because many occurred through voter referendum. The debate remains contentious and ongoing.<sup>4</sup>

The academic literature on marijuana use is mixed. Shepard and Blackley (2007) find that marijuana prosecution is associated with increases in homicides, burglaries, motor vehicle thefts, and larcenies along with subsequent increases in hard drug arrests. While Pacula, Powell, Heaton, and Sevigny (2013) argue that medical marijuana dispensaries increase the consumption of marijuana and alcohol, and lead to more alcohol-related traffic fatalities, Anderson and Rees (2013) suggest that dispensaries do not appear to have been an important contributor to the increase in marijuana use in Colorado and there is no evidence that dispensaries caused an increase in alcohol consumption. A recent study by Wen, Hockenberry, and Cummings (2014) suggest that MML implementation increases marijuana use mainly

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<sup>3</sup><http://www.prohibitioncosts.org/endorsers/#sthash.HgXSb66j.dpuf> [accessed November 1, 2014]

<sup>4</sup>Currently, a proposed constitutional amendment in Florida could potentially make it the first state in the South to legalize medicinal marijuana. It has become one of the key points of contention in the state’s gubernatorial race. <http://online.wsj.com/articles/floridas-medical-pot-vote-turns-into-political-party-battle-1414202150> [accessed October 31, 2014]



among those over 21 but finds no evidence of spillovers to other substance use.

### **3.2 Legalization of Civil Union and Domestic Partnerships Status in the U.S.**

Policies in favor of same-sex marriage (or civil unions and domestic partnerships) are also widely associated with liberal policies and agendas (Soule and Earl, 2001; Kane, 2003; Soule, 2004). In the United States, lesbian, gay, bisexual and transgender (LGBT) rights related laws are determined by each state and local jurisdiction. While the federal government traditionally recognizes any marriage that is recognized by the state, the federal Defense of Marriage Act of 1996 explicitly defines marriage as between a man and a woman. In the landmark *United States v. Windsor* case, the Supreme Court ruled on June 26, 2013 that section 3 of the Defense of Marriage Act is unconstitutional and the federal government is required to recognize marriages performed in states where same-sex marriage has been legalized, and provide federal rights, privileges and benefits. As of 2014, thirty-five states and District of Columbia offer marriage to same-sex couples.

Because the legalization of same-sex marriages occurred relatively recently (Vermont was the first state to legalize same sex-sex marriage in September 2009) and they all occurred after our sample period, we take advantage of changes in the legal status of same-sex civil union and domestic partnership across states. Civil unions and domestic partnerships are a non-religious state-sanctioned form of partnership. The formalities for entering a civil union and the benefits and responsibilities of the parties tend to be similar to those relating to marriage in most states. Like same-sex marriages before 2013, same-sex civil unions do not confer federal benefits and are not recognized under the federal law.

During our sample period from 1998 to 2008, ten states and the District of Columbia changed the legal status of same-sex civil union and domestic partnership. Table A2 lists the dates that changed the status of civil unions and domestic partnerships.<sup>5</sup>

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<sup>5</sup>In many of these states, the legalization of same-sex marriage has since superseded civil union and domestic partnership status.

### 3.3 Passing of Abortion Restrictions

Support for legal abortion has long been considered an integral part of the liberal agenda and policies in the U.S. and many other countries (Noelle-Neumann, 1998; Brewer and Wilcox, 2005; Poteat and Mereish, 2012). While there is no consensus among U.S. residents on whether women should have the legal right to abortion under any circumstance, various polls and surveys by Gallup, Pew Center and other institutes suggests that those who identify themselves as liberal are significantly more likely to be in favor of abortion rights for women (Gallup, 2013).

From a legal point of view, abortion have traditionally been prohibited across many states during the early 20th century. The landmark United States Supreme Court 1973 decision *Roe v. Wade* invalidated the prior prohibitions and set the legal framework for the availability of abortion. The ruling essentially gave women the legal right to have an abortion up to the third trimester. However, it was later modified due to the 1992 *Planned Parenthood v. Casey*<sup>6</sup> case which changed the trimester threshold to the stage of fetal viability - i.e., the state at which the embryo is “able to survive outside the mother’s womb, albeit with artificial aid”. *Casey* further lowered the legal barriers for states to justify and impose restrictions on abortion. Since then, various states have imposed different forms of restriction on abortion through new state legislatures or amendments to the state constitution. According to the Guttmacher Institute, the number of abortion restrictions across various states in the U.S. has increased substantially over the past two decades (Guttmacher Institute, 2015). The number and extent of restrictions however vary considerably by state and time. They range from extended waiting periods and mandatory counseling, to limitations on insurance coverage and near-total abortion bans (Guttmacher Institute, 2015).

We collect the data on the timing of abortion restrictions passed across all the states from the Guttmacher Institute and various other public sources. In our analysis we use the change in the number of abortion restrictions in each state over time as the proxy for the change in the level of legal barrier for abortion in that state. The number of abortion

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<sup>6</sup>505 U.S. 833

restrictions across the states range from 0 to 15 during our sample period, with an average of about 5 restrictions and a standard deviation of 3 over the whole sample period. The average number of restrictions changes from about 4 restrictions in 1994 to 6 in 2009. Figure A1 in Appendix A illustrates the number of enacted abortion restrictions in each state in 1994 and 2009.<sup>7</sup>

## 4 Data

Our data is collected from various sources. To construct the patenting rates at the state and individual inventor levels, we used the Lai, D’Amour, Yu, Sun, and Flemming (2013) dataset available on the Patent Network Dataverse. The data covers all the patents granted by the USPTO between 1975 and 2010. Due to the long delays between application and grant dates, there is considerable right truncation in the number of granted patents in the last four years of the sample and hence we only used the data for the period between 1993 and 2006.<sup>8</sup> We begin our sample in 1993 based on the availability of data for our control variables and the first legalization date of 1996.

We collect data on the legalization dates of medicinal marijuana and same-sex civil unions and domestic partnerships from various public sources as well as prior research (Wen, Hockenberry, and Cummings, 2014). Data on abortion restrictions are collected from the Guttmacher Institute (2015) and other online public sources.

We also collect the yearly total public expenditure and education expenditure by each state from the U.S. Census Bureau. Data on business R&D per state is retrieved from the National Science Foundation’s Science and Engineering Indicators dataset. We obtain data on the number of individuals with a bachelor’s degree from Census Education Attainment Reports. The data on the migration of professional service workers and degreed individuals are compiled from the American Community Survey 2008-2012 and American Community Survey 2009-2013, respectively.

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<sup>7</sup>To the extent that certain restrictions have differing impacts, we also experiment with different weightings of restrictions and find our results are largely consistent.

<sup>8</sup>We use data up to 2009 in unreported analysis and find largely consistent results.

## 5 Empirical Framework

Medicinal marijuana and same-sex civil union legalization occurred at different times across states. Also, various states have passed additional restrictions on abortion at different points of times. We exploit the variation in these timings to estimate the causal effect of legalization on innovation. Our strategy is similar in spirit to a differences-in-differences (DD) strategy, where we compare the changes in the outcomes of states that have experienced a policy change in a particular year to other states that have not had the same change at the same time. Our baseline estimates always control for state and year fixed effects. State fixed effects control for all time-invariant differences between states, such as geographic characteristics and political orientation. Year fixed effects control for changes over time that affect all states similarly (e.g., national policy changes, macroeconomic growth). Our baseline specification also include state-specific and time-varying controls on R&D spending, the share of education expenditures, the number of adults with at least a bachelor’s degree, and total state expenditure. Our identification strategy assumes that the timing of legalization is uncorrelated with our outcomes of interest conditional on baseline controls. We check the validity of this assumption later in the section on robustness. The main estimating equation we use to examine the effect of liberalization policies on patenting is as follows:

$$\text{LoggedPatentCount}_{st} = \alpha + \beta(\text{Legalization}_{st}) + \theta X_{st} + \delta \text{State}_s + \mu \text{Year}_t + \epsilon_{st} \quad (1)$$

where *LoggedPatentCount* is the logged count (plus one) of state *s*’s patents granted in year *t*. In the case of the two liberalization policies, *Legalization<sub>st</sub>* is equal to 1 after state *s* legalizes marijuana or same-sex civil union in year *t*. In the case of abortion restrictions, *Legalization<sub>st</sub>* is equal to the number of restrictions in effect in state *s* in year *t*.  $\beta$  is the key coefficient of interest in all estimations. In the regressions with the legalization of medicinal marijuana and legalization of same-sex civil unions as the treatment,  $\beta$  captures the change in the average patenting rate after the policy change. In regressions with the passage of

abortion restrictions as the treatment,  $\beta$  captures the change in average patenting rate due to the passage of an additional restriction.  $X_{st}$  is a vector of controls for state-specific and time varying characteristics, such as state and education expenditure.  $State_s$  and  $Year_t$  are state and year fixed effects, respectively. We employ ordinary least squares (OLS) and cluster standard errors by state to adjust for autocorrelation within states (Bertrand, Duflo, and Mullainathan, 2004) in all of our specifications. We also employ yearly treatment to evaluate the timing of each policy and test for any pre-trends before the enactment of liberalization policies. We further use falsification tests to validate our main findings.

## 6 Results

### 6.1 Main Results

Table 1 provides the summary statistics for our main variables. Each state produces on average 530 patents per year. Also, an average state has an annual spending expenditure of \$14.5 billion, from which approximately 32% are spent on education at primary, secondary and post-secondary levels. On average, businesses and institutions spend about \$2 billion on research and development at the state-level.

Given Glaeser (2005)’s argument that human capital can explain a large fraction of the relationship between growth and Florida (2002c)’s “creativity index”, we first explore whether there is a correlation between the fraction of educated adults (measured by the number of adults with a bachelor’s degree in a state) and patenting. In Table 2 column (1), we show that there is indeed a positive correlation between the number of degreed individuals in a state and patenting. The low significance levels are likely due to the inclusion of state fixed effects and that the number of individuals with bachelor degrees is relatively stable over time within each state. In column (2), we include three additional state-specific and time-varying controls: business R&D expenditure (logged), state expenditure (logged), and share of education expenditure from the state expenditure. As expected, the estimates in column 2 suggest that both R&D expenditure and total public expenditure have a significant

and positive impact on patenting rate. Because the data for the number of individuals with bachelor degrees end in 2006 and there is considerable right truncation in the number of granted patents after 2006, we use the sample up to 2006 for our main estimations.

Table 3 reports our main results on the impact of medicinal marijuana legalization on patenting. All specifications include year- and state-fixed effects. We use the log-normalized number of patents at the state level because of the skewness of data. Column 1 reports baseline estimates while columns 2 includes additional controls. The estimates suggest that the legalization of medicinal marijuana increases patenting rate by about 16%. That would roughly translate to an average increase of around 350 patents per state per year.

Table 4 reports the main results on the impact of same-sex civil union and domestic partnership legalizations on patenting. The findings show that legalization of same-sex civil unions and domestic partnerships raises patenting rate by roughly 10%, or an increase of 200 patents.

Table 5 reports the estimates for the impact of abortion restrictions on patenting. The estimates in columns 1 and 2 suggest that passing an additional abortion restriction lead to about 2% decline in patenting rate, roughly equivalent to 40 fewer patents.

Taken together, our main results suggest that liberalization policies have a significant and economically large impact on patenting. We examine the robustness of our main findings below.

## 6.2 Robustness

### 6.2.1 Yearly-Treatment Effects

So far our analysis has assumed that timing of these policies are uncorrelated with factors that determine the outcomes of interest, conditional on the baseline controls. However, if treated states experienced a significant change in patenting prior to the policy change, then our estimates may be confounded with a pre-trend, undermining the effect of  $\beta$  as a treatment effect. In the absence of a pre-trend, the results are less likely to be driven by endogenous timing. To investigate the presence of pre-trends, we plot the yearly treatment estimates

associated with the legalization of medicinal marijuana and the legalization of same-sex civil unions and domestic partnerships (Figures 1 and 2). Each point on the depicted yearly treatment graphs is the estimated difference between treated and control states in the years before and after the legalization for patenting. Both graphs show an increase in patenting starting 1 to 3 years after the policy change. There is little evidence of upward trends before the implementation of the two liberalization policies. Not surprisingly, these figures suggest a delay between the policy implementations and their impacts on patenting. Overall, the results suggest that both liberalization policies have a positive impact on patenting.<sup>9</sup>

Another concern is that the estimates may be driven by other concurrent unobservable policy changes that have positively influenced the rate of patenting. To address this potential issue, we checked various public records to see if we can identify simultaneous policy changes in the states that have implemented these legalizations. We could not find consistent evidence of simultaneous policy changes at the state level. Moreover, our set of controls at least partially captures the effect of unobserved policy changes that impact patenting through increased public or R&D expenditure. In short, while we cannot rule out its possibility, we do not find evidence that suggests our estimates are fully driven by other concurrent policy changes.

### 6.2.2 Falsification Test

In order to further test the validity of our estimations, we used a series of falsification tests in the spirit of those performed by Bertrand, Duflo, and Mullainathan (2004). The core idea is to assign a series of placebo legalization dates to random states at random years and see how often we would obtain significant results with these placebo treatments. Since the placebo legalization dates are selected randomly, we should see a significant effect (i.e., rejecting no effect) at the 5 percent level roughly 5 percent of the time.

In order to implement the falsification test, we created a hundred set of random placebo

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<sup>9</sup>Since there are multiple treatments dates in each state in the case of abortion restrictions, there is no clear before and after treatment periods and thus we cannot produce the yearly treatment graphs for this case.

legalization dates for each of the states in the sample. Then we repeated the main regressions 100 times (for each set of placebo dates) for the dependent variable with the placebo dates along with the full set of control variables. We obtained significant estimates for the placebo treatments 4 percent of time. Overall, the results validate our main findings and suggest that they are not driven by spurious trends in the data and are indeed linked to the observed policy changes.

### **6.2.3 Alternative Dependent Variable**

While patenting is predominantly used to measure innovation and is our primary outcome of interest, we also experiment with an alternative dependent variable that is associated with creativity: artistic product per capita. The yearly artistic product per capita for each state is collected from the U.S. Bureau of Economic Analysis. The data starts in 1997 and we use the available data until 2009.

Table 6 examines the impact of each policy on artistic product per capita. We find that legalization of medicinal marijuana and same-sex civil unions increase artistic product per capita by about 7.5% and 7%, respectively. In contrast, passing an additional abortion restriction lead to about 1% decline in artistic product per capita. The magnitude and significance of these findings are in line with our main results - more (less) liberal policies are associated with an increase (decrease) in innovative outcomes.

## **6.3 Mechanisms**

The goal of this section is to provide evidence on whether the reported changes in innovation after the implementation of these policies is attributed to the net flow of talent from (or to) other states and/or to changes in the creativity of existing residents. We use three separate analyses to evaluate the presence of these two mechanisms. We also examine whether the increase in patenting due to the legalization of medicinal marijuana is driven by increased consumption of marijuana.

First, we compare changes in the total number of inventors in the treated states to control



states after the policy changes. To do so, we used the main regressions with the total number of inventors per state per year as the dependent variable. The results for each policy change is reported in Table 7. The estimates in columns 1 and 2 suggest an increase in the total number of inventors by 16% after the legalization of medicinal marijuana and by 10% after the legalization of same-sex civil unions and domestic partnerships. The increase in the total number of inventors may come from two sources. It may be due to the migration of inventors from other states, or it can also be driven by an increase in the number of state residents who engage in more inventive activities after policy changes. On the contrary, the estimates in column 3 suggests a decline of about 2.5% in the number of inventors due to the passage of each additional abortion restriction. The decline can be the result of inventors leaving a state or relatively fewer residents engaging in inventive activities for the first time. We explore both mechanisms below.

Second, to examine whether these policies are correlated with inter-state mobility of talent, we examine the relationship between the status of each state with regards to each policy in 2008 and the net yearly flow of skilled labor, measured by individuals in professional, scientific and managerial occupations as well as individuals with at least a bachelor's degree into that state. A negative net flow to a state means that the state has on average lost part of its talent to other states. The data on inter-state migration of individuals based on occupation is extracted and compiled from the U.S. Census American Community Survey 2008-2012, which records the average migration rate of each state between 2008 and 2012. The data on inter-state migration of individuals with at least a bachelor's degree is extracted and compiled from the U.S. Census American Community Survey 2009-2013, which records the average migration rate of each state between 2009 and 2013.

In Tables 8 and 9, we estimate the relationship between each policy and the two inter-state net migration rates using the full set of control variables. The results in columns 1 and 2 of both tables suggest a strong positive association between the two liberalization policies and the measures of the inter-state flow of talent to a state. In contrast, the estimates in columns 3 of both tables suggest a strong negative correlation between the passing of

additional abortion restrictions and the two outcome measures of talent migration to a state. One caveat is that the cross-sectional nature of the survey data on migration does not allow us to take advantage of the staggered timing of these two policies across states, and consequently precludes us from interpreting our estimates as causal effects. Nevertheless, the results suggest a positive association between the liberalization policies and the attraction of skilled labor to a state.

In the third analysis, we examine whether liberalization policies impact innovative outcomes for existing residents. We exclude all inventors that have changed their state locations at any point of their inventive careers. We examine whether there has been any change in the patenting rate of inventors who have been residing in the treated states for their entire inventive career post-legalization relative to others who have been residing in the control states for their entire careers. The state location of inventors is identified based on the address that they self-report on each patent document. Within the treated states, we only include those inventors that have at least one patent before the legalization dates to ensure that they are not inventors that start patenting after moving to treated states post-legalization. In the case of abortion restrictions, since there have typically been multiple policy changes in each state over time, there are no clear before and after policy enactment periods. Thus identifying the inventors with pre-treatment patenting experience is not feasible. As a result, we only perform this analysis for the legalization of medicinal marijuana and the legalization of same-sex civil unions and domestic partnerships.

Columns 1 and 2 in Table 10 reports the results for legalization of medicinal marijuana and legalization of same-sex civil unions and domestic partnerships, respectively. We also included two additional individual-level controls for the inventive experience of the individual and its square term to capture the potential non-linearity of experience on inventive productivity. The estimated coefficients of both treatment effects are positive and significant, suggesting that these two liberalization policies increase the innovative output of current residents by 2-3%. Note that these estimated increases might be driven by at least two mechanisms. First, it might be driven solely by increasing the quality and/or quantity of

the existing residents' innovative activities in the treated states. It might also be driven by the interaction of current residents with the inflow of talent from other regions. With our current data, we cannot separate these two mechanisms. Nevertheless, we can conclude that the growth in the patenting rate of treated states is not entirely attributed to the migration of talent and is at least in part attributed to the increase in patenting by existing residents.

Taken together, we cautiously interpret these results to suggest that liberalizations policies not only increase innovative outcomes by attracting talent from other regions, but also by increasing the creativity of existing residents. Further research is needed to disentangle the two mechanisms more thoroughly and provide nuanced policy implications.

We also examine whether the increase in patenting after the legalization of medicinal marijuana can be explained by an increase in the consumption of marijuana in the treated states (Table 11). Prior research provides some evidence that there is an increase in marijuana consumption post-legalization (Wen, Hockenberry, and Cummings, 2014). Meanwhile, descriptive and anecdotal evidence suggest a correlation between consumption of marijuana and creativity (Eisenman, Grossman, and Goldstein, 1980; Bourassa and Vaugois, 2001). In order to test this idea, we collected state-level marijuana consumption data from the National Survey on Drug Use and Health (Department of Health and Human Services, 2012). We repeat the regressions for the legalization of medicinal marijuana and replace the post-legalization dummy with the marijuana consumption level variable. To the extent that the positive effect of policy is fully or partially driven by an increase in the consumption of marijuana, we would expect to see a positive estimated coefficient for the consumption variable. Instead, the estimates suggest a negative and insignificant relationship between patenting and the level of marijuana consumption in a state. This suggests that the increase in patenting in treated states post-legalization of medicinal marijuana is unlikely to be driven by an increase in the consumption of marijuana in those states.

## 7 Conclusion and Implications

What drives regional development is a central question to economic geography and innovation. In this paper we exploit the staggered timing of the legalization of medicinal marijuana, same-sex civil unions and domestic partnerships, and abortion restrictions across different states in the U.S. to test the impact of liberalization policies on regional innovation. Our estimates suggest that liberalization policies have economically large and statistically significant impacts on innovative outcomes.

The variation in implementation of such policies, and more broadly, the changes in liberalization across geographical regions can explain some of the differences in innovation. While these policies all provide proxies of different dimensions to liberalization, we employ all three policies to increase the external validity of our findings. We find evidence consistent with the idea that settings with more liberal policies may not only increase innovation by attracting skilled individuals, they can also boost the creativity of the existing population. However, given the cross-sectional nature of the data on migration, we cannot track movement of inventors at the individual level. Thus, we cannot conclude whether the increase in patenting for the existing population is driven by a more liberal environment facilitating innovation or the spillover effect of mobile inventors on the existing population. Future research using more fine-grained data on migration can shed additional light on the underlying mechanisms.

These findings have policy and managerial implications. At the national and regional level, enacting more liberal policies can potentially lead to superior innovative performance and create competitive advantage. Some states are already in the process of reviewing the impact of civil right laws on the economic productivity of the region. For example, Michigan's Department of Civil Rights recently argued that one of the most prominent effects of the state's lack of LGBT-inclusive policies was out-migration, and called for the state legislature to expand LGBT-inclusive policies in order to retain and attract skilled individuals (Michigan Department of Civil Rights, 2013). Given the considerable impact of institutional environment on organizations' performance, the results also highlight the importance of location decisions for organizations (Alcacer and Chung, 2007) and may impact the ability

of organizations to attract and retain skilled workers. In recent years, 30 of the Fortune 500 companies urged the Senate to include LGBT benefits in immigration reform packages as they are losing “productivity when those families are separated” and have ‘missed opportunities to bring the best and the brightest to the United States when their sexual orientation means they cannot bring their family with them.” (International Business Times, 2013). At a more micro level, these findings suggest that companies with more liberal policies may achieve higher organization-wide creativity levels by spurring ideas and innovation through workforce diversity (The Williams Institute, UCLA, 2013).

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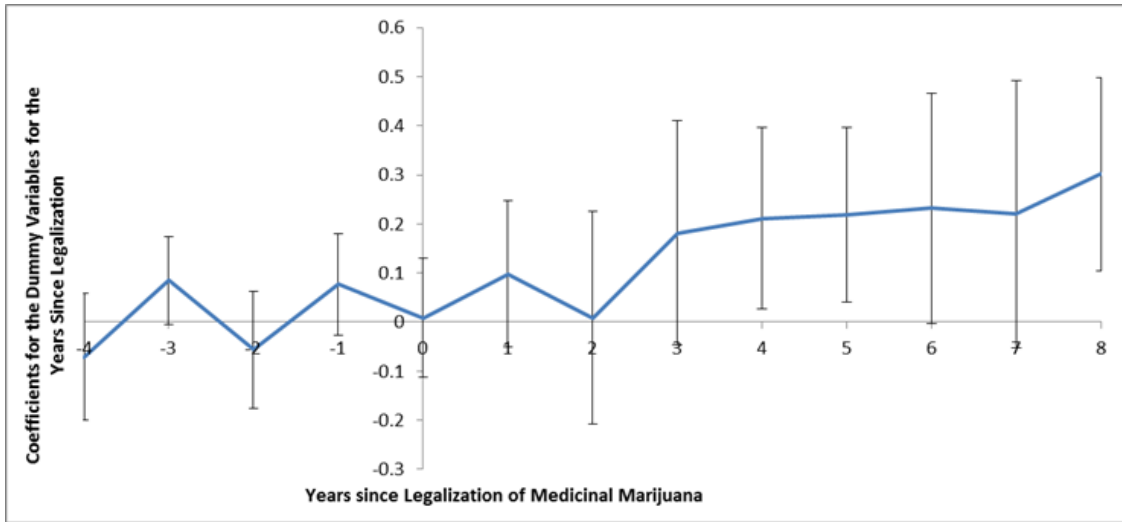


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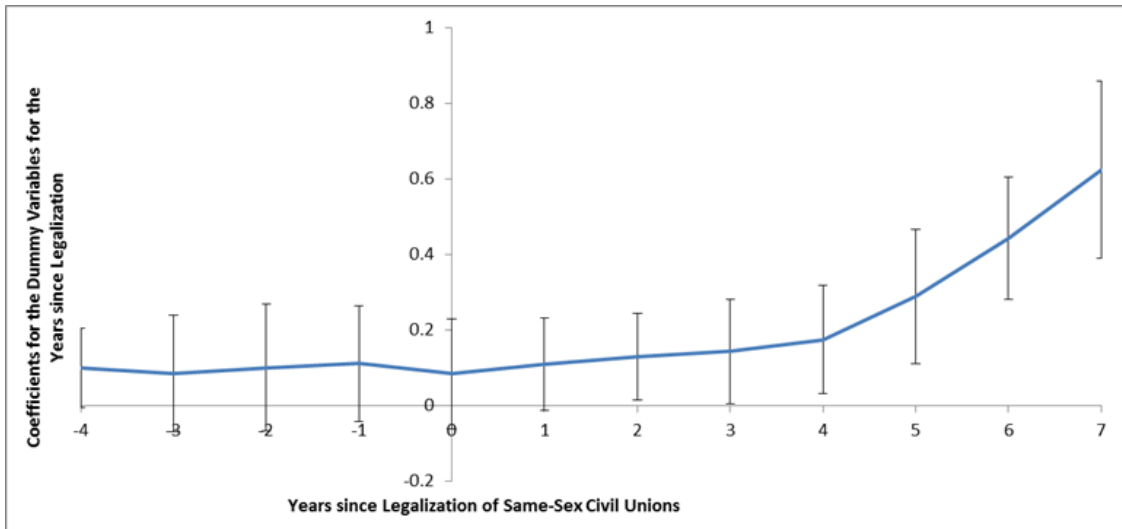
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Figure 1: Yearly Treatment Effect of Legalization of Medicinal Marijuana on Patenting



Notes: Figure plots estimated year by year pre- and post-legalization changes in patenting from OLS regressions with year fixed effects and controls. Each point represents the estimated difference between the treated (legalized) and control (non-legalized) state in each year, along with upper and lower bounds for 95% confidence intervals.

Figure 2: Yearly Treatment Effect of Legalization of Civil Unions on Patenting



Notes: Figure plots estimated year by year pre- and post-legalization changes in patenting from OLS regressions with year fixed effects and controls. Each point represents the estimated difference between the treated (legalized) and control (non-legalized) state in each year, along with upper and lower bounds for 95% confidence intervals.

Table 1: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
<i>Main dependent variables:</i>					
Number of Utility Patents (logged)	1071	6.285	1.761	0	10.249
Artistic Product Per Capita	714	1613.002	1113.017	601.821	8773.690
<i>Migration variables:</i>					
Net migration rate of professionals	51	0.114	1.099	-4	3.6
Net migration rate of individuals with a bachelor degree	612	-0.001	0.080	-0.560	0.294
<i>Explanatory variables:</i>					
Medicinal Marijuana Legalization	1071	0.104	0.305	0	1
Civil Union Legalization	1071	0.061	0.239	0	1
Abortion Restrictions	1071	4.922	3.271	0	15
<i>Controls:</i>					
Business R&D (logged)	764	7.676	1.468	4.007	11.306
State Expenditure (logged)	950	16.499	1.001	14.263	19.366
Share of Education Expenditure	950	31.784	5.587	16.061	44.58
Number of individuals with a bachelor degree (logged)	663	10.855	1.062	8.474	13.459
Population (logged)	1071	15.015	1.032	13.025	17.436

Notes: Each observation is at the state-year level.

Table 2: Baseline Results: Education and Innovation

	Logged Patent Count	
	(1)	(2)
Logged Number of Individuals with a Bachelors	0.274* (0.145)	0.193 (0.135)
Logged Business R&D Expenditure (Lagged)		0.124** (0.060)
Logged Total State Expenditure (Lagged)		0.545** (0.227)
Share Of Education Expenditure (Lagged)		0.001 (0.005)
Observations	663	499
R-squared	0.544	0.603

Notes: All estimates are from panel ordinary-least-squares (OLS) models. All specifications include state and year fixed effects. Robust standard errors are clustered by state.  
 \*\*\*p<0.01, \*\* p<0.05, \* p<0.1

Table 3: The Impact of Medicinal Marijuana Legalization on Patenting

	Logged Patent Count	
	(1)	(2)
Medicinal Marijuana Legalization	0.168** (0.076)	0.163** (0.069)
Logged Business R&D Expenditure (Lagged)		0.106* (0.058)
Logged State Expenditure (Lagged)		0.585*** (0.209)
Share Of Education Expenditure (Lagged)		0.000 (0.004)
Logged number of degreed individuals		0.170 (0.121)
Number of states	50	50
Observations	499	499
R-squared	0.592	0.628

Notes: This table examines the impact of medicinal marijuana legalization on patenting. All specifications include state and year fixed effects. Robust standard errors are clustered by state.

\*\*\*p<0.01, \*\* p<0.05, \* p<0.1

Table 4: The Impact of Civil Union Legalization on Patenting

	Logged Patent Count	
	(1)	(2)
Civil Union/Domestic Partnership Legalization	0.104*	0.106***
	(0.056)	(0.032)
Logged Business R&D Expenditure (lagged)		0.124**
		(0.061)
Logged State Expenditure (lagged)		0.543***
		(0.209)
Share Of Education Expenditure (lagged)		-0.001
		(0.005)
Logged number of degreed individuals		0.195
		(0.135)
Number of states	50	50
Observations	499	499
R-squared	0.570	0.608

Notes: This table examines the impact of the legalizaiton of same-sex civil unions and domestic partnerships on patenting. All specifications include state and year fixed effects. Robust standard errors are clustered by state.  
\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 5: The Impact of Abortion Restrictions on Patenting

	Logged Patent Count	
	(1)	(2)
Number of abortion restrictions	-0.023*	-0.026**
	(0.013)	(0.012)
Logged Business R&D Expenditure (lagged)		0.119**
		(0.058)
Logged State Expenditure (lagged)		0.612***
		(0.215)
Share Of Education Expenditure (lagged)		-0.000
		(0.005)
Logged number of degreed individuals		0.167
		(0.131)
Number of states	50	50
Observations	499	499
R-squared	0.575	0.615

Notes: This table examines the impact of state-level abortion restrictions on patenting and artistic product per capita. All specifications include state and year fixed effects. Robust standard errors are clustered by state.  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1



Table 6: The Impact of Policies on Artistic Product

	Artistic Product per Capita		
	(1)	(2)	(3)
Medicinal Marijuana Legalization	121.316** (50.264)		
Civil Union/Domestic Partnership Legalization		113.821** (54.278)	
Number of abortion restrictions			-17.013** (8.133)
Logged Business R&D (lagged)	-11.633 (26.676)	-6.022 (27.968)	-3.102 (28.438)
Logged State Expenditure (lagged)	292.294 (327.502)	235.093 (356.038)	288.518 (345.335)
Share of Education Expenditure	13.474** (5.107)	12.235** (5.314)	13.528** (5.907)
Logged number of degreed individuals	95.744 (101.029)	104.254 (111.507)	88.646 (110.675)
Number of states	50	50	50
Observations	399	399	399
R-squared	0.800	0.794	0.792

Notes: This table examines the impact of policies on artistic product. All specifications include state and year fixed effects. Robust standard errors are clustered by state.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 7: Change in Number of Inventors After Policy Changes

	Number of Inventors		
	(1)	(2)	(3)
Medicinal Marijuana Legalization	0.145*		
	(0.077)		
Civil Union/Domestic Partnership Legalization		0.100***	
		(0.031)	
Number of abortion restrictions			-0.025*
			(0.013)
Logged Business R&D (lagged)	0.062	0.078*	0.073*
	(0.042)	(0.046)	(0.043)
Logged State Expenditure (lagged)	0.479**	0.441**	0.506**
	(0.200)	(0.202)	(0.199)
Share of Education Expenditure	0.000	-0.001	-0.000
	(0.004)	(0.004)	(0.004)
Logged number of degreed individuals	0.242**	0.265**	0.238**
	(0.100)	(0.114)	(0.105)
Number of states	50	50	50
Observations	499	499	499
R-squared	0.593	0.574	0.582

Notes: This table examines the change in total number of inventors in treated states relative to control states after liberalization policies have been implemented. All specifications include state and year fixed effects. Robust standard errors are clustered by state.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 8: Migration of Professional Service Workers and Liberalization

	Net migration rate of professional workers		
	(1)	(2)	(3)
Medicinal Marijuana Legalization	0.974*** (0.219)		
Civil Union/Domestic Partnership Legalization		0.747** (0.301)	
Number of abortion restrictions			-0.091*** (0.033)
Logged Business R&D (lagged)	-0.043 (0.146)	-0.048 (0.186)	0.023 (0.140)
Logged State Expenditure (lagged)	-1.671** (0.680)	-1.440* (0.680)	-1.596** (0.717)
Share of Education Expenditure (lagged)	-0.027 (0.025)	-0.012 (0.026)	-0.001 (0.030)
Logged State Population	1.620*** (0.640)	1.390** (0.678)	1.580** (0.699)
Observations	50	50	50
R-squared	0.161	0.307	0.187

Notes: This table examines the relationship between migration of professional-service workers and policy status of states in 2007. The dependent variable is the mean yearly net migration rate of individuals in professional, scientific, or managerial occupations between 2008 and 2012 compiled from the American Community Survey 2008-2012. The independent variables are from 2008. All estimates are from ordinary-least-squares (OLS) models. Robust standard errors are clustered by state.  
\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 9: Migration of Individuals with Bachelor Degrees and Liberalization

	Net migration rate of individuals with Bachelor degrees		
	(1)	(2)	(3)
Medicinal Marijuana Legalization	0.563*** (0.146)		
Civil Union/Domestic Partnership Legalization		0.433*** (0.159)	
Number of abortion restrictions			-0.049** (0.033)
Logged Business R&D (lagged)	-0.066 (0.110)	-0.069 (0.128)	-0.025 (0.106)
Logged State Expenditure (lagged)	-1.764** (0.503)	-1.631*** (0.511)	-1.701*** (0.619)
Share of Education Expenditure (lagged)	-0.010 (0.021)	-0.001 (0.021)	0.004 (0.022)
Logged state population	1.881*** (0.484)	1.749*** (0.485)	1.835*** (0.578)
Observations	50	50	50
R-squared	0.403	0.327	0.479

Notes: This table examines the relationship between migration of individuals with bachelor degrees and the policy status of states in 2007. The dependent variable is the mean yearly net migration rate of individuals in with bachelor degrees between 2009 and 2013 compiled from the American Community Survey 2009-2013. All estimates are from ordinary-least-squares (OLS) models. Robust standard errors are clustered by state.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 10: The Impact of Liberalization Policies on Patenting at the Individual Level  
(Excluding Movers)

	Logged Patent Count (1)	Logged Patent Count (2)
Medicinal Marijuana Legalization	0.035*** (0.005)	
Civil Union/Domestic Partnership Legalization		0.026*** (0.004)
Logged Business R&D	-0.007 (0.005)	-0.005 (0.005)
Logged State Expenditure	0.065 (0.080)	-0.027 (0.032)
Share of Education Expenditure	0.000 (0.001)	0.000 (0.000)
Logged number of degreed individuals	-0.055*** (0.019)	-0.057*** (0.014)
Inventive Experience	-0.039*** (0.006)	-0.040 (0.004)
Patent Experience (squared)	0.000** (0.000)	0.000*** (0.000)
Number of individuals	845564	964656
Observations	6136996	6872690
R-squared	0.125	0.134

Notes: This table examines the impact of liberalization policies at the individual inventor level and excludes inventors that have moved states during the course of their inventive careers. All specifications include state and year fixed effects. Robust standard errors are clustered by state.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 11: Does Marijuana Consumption Impact Patenting?

	Logged Patent Count
Marijuana Consumption (Logged)	-0.080 (0.100)
Logged Business R&D	0.058 (0.056)
Logged State Expenditure	0.151 (0.210)
Share of Education Expenditure	-0.001 (0.004)
Logged number of degreed individuals	0.220* (0.122)
Number of States	50
Observations	349
R-squared	0.672

Notes: All specifications include state and year fixed effects.

Robust standard errors are clustered by state.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

# Appendices

## Appendix A Timing of Liberalization Policies

Table A1: Effective Time of State Medical Marijuana Laws (MML)

State	Effective
Alaska	1999
Arizona	2011
California	1996
Colorado	2001
Connecticut	2012
Delaware	2011
District of Columbia	2010
Hawaii	2000
Illinois	2014
Maine	1999
Massachusetts	2013
Maryland	2014
Michigan	2008
Montana	2004
Nevada	2001
New Hampshire	2013
New Jersey	2010
New Mexico	2007
Oregon	1998
Rhode Island	2006
Vermont	2004
Washington	1998

Source: This table lists the dates of medicinal marijuana legalization across states. For additional details, see Wen, Hockenberry, and Cummings (2014)

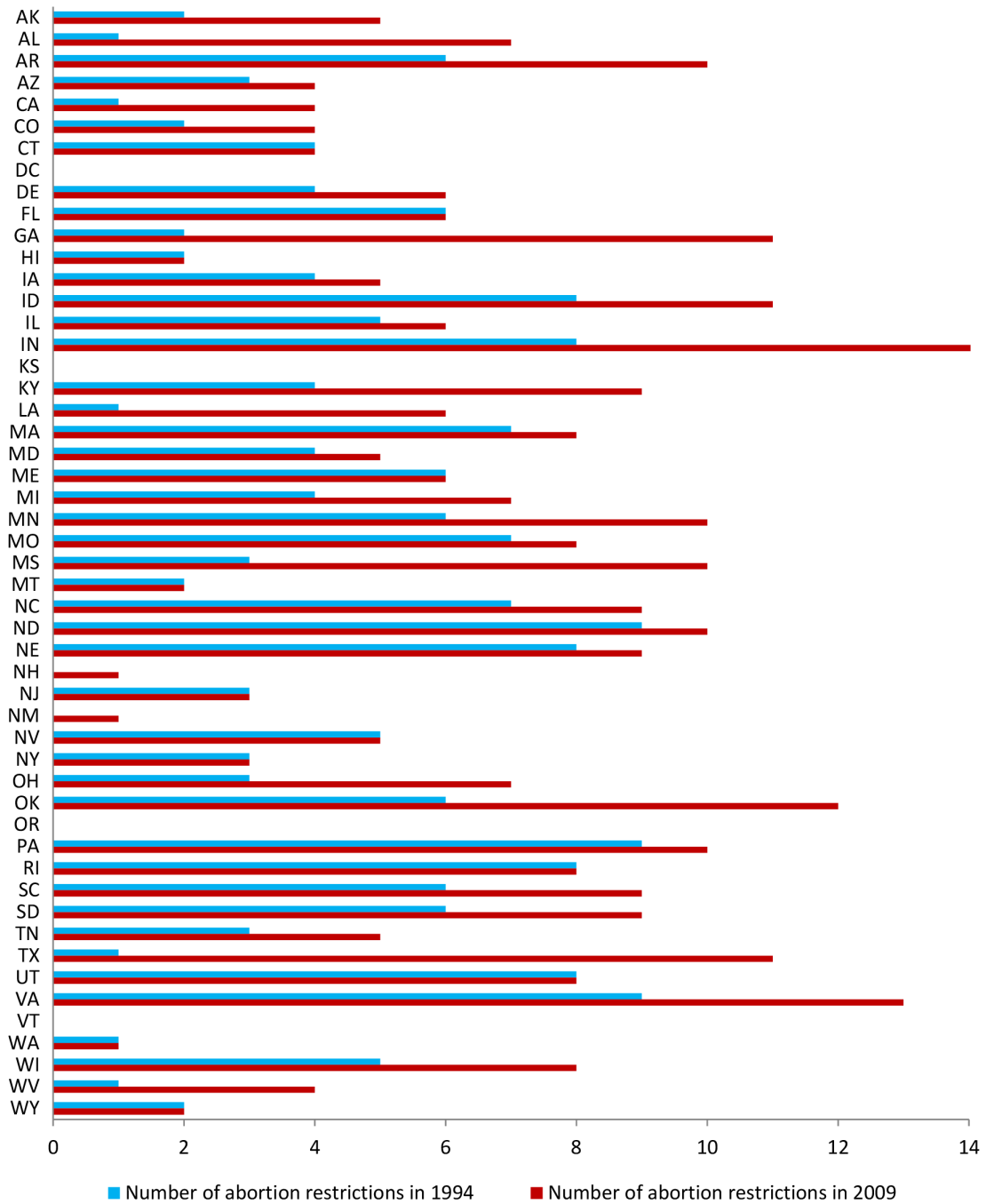
Table A2: Effective Time of Civil Union and Domestic Partnership Status

State	Effective
California	2005
Colorado	2009
Connecticut	2005
District of Columbia	2002
Hawaii	1998
Maine	2005
Maryland	2008
Nevada	2009
New Hampshire	2007
New Jersey	2007
Oregon	2008
Rhode Island	2011
Vermont	2000
Washington	2007
Wisconsin	2009

Source: This table lists the dates that changed the status of civil unions and domestic partnerships in the United States. Civil unions and domestic partnerships in the United States are determined by each state or local jurisdiction.



Figure A1: The Number of Abortion Restrictions Enacted Across States



Notes: Figure plots the number abortions restrictions enacted by each state in 1994 and in 2009 (Guttmacher Institute).