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ABSTRACT

The Pot Rush: Is Legalized Marijuana a Positive Local Amenity?*

This paper examines the amenity value of legalized marijuana by analyzing the impact of marijuana legalization on migration to Colorado. Colorado is the pioneering state in this area having legalized medical marijuana in 2000 and recreational marijuana in 2012. We test whether potential migrants to Colorado view legalized marijuana as a positive or negative local amenity. We use the synthetic control methodology to examine in- and out-migration to/from Colorado versus migration to/from counterfactual versions of Colorado that have not legalized marijuana. We find strong evidence that potential migrants view legalized marijuana as a positive amenity with in-migration significantly higher in Colorado compared with synthetic- Colorado after the writing of the Ogden memo in 2009 that effectively allowed state laws already in place to be activated, and additionally after marijuana was legalized in 2013 for recreational use. When we employ permutation methods to assess the statistical likelihood of our results given our sample, we find that Colorado is a clear and significant outlier. We find no evidence for changes in out-migration from Colorado suggesting that marijuana legalization did not change the equilibrium for individuals already living in the state.

JEL Classification: I18, R23, K42, C22

Keywords: marijuana legalization, interstate migration, synthetic controls

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1. Introduction

In the past decade, a number of US states have legalized marijuana either for medical or recreational proposes. A large literature has examined the impact of these law changes on the consumption of marijuana (Jacobi and Sovinsky 2016; Pacula 2010; Cerdá et al. 2017) and other related vices such as alcohol and tobacco (DiNardo and Lemieux 2001), and on a wide range of health outcomes including mental health (Zammit 2002; Henquet 2005), suicide (Anderson et al. 2012), car accidents (Anderson et al. 2013) and crime (Dragone et al. 2016). One so far unexamined question has been whether individuals, on average, view the legalization of marijuana as a positive or negative amenity and whether this has led to changes in individuals' migration decisions and the spatial equilibrium of the US population.

There is a large literature examining how household migration decisions help shape human geography (e.g. Blanchard and Katz 1992; Glaeser, Ponzetto, and Tobio 2014). The typical starting point is the neoclassical model of spatial equilibrium pioneered by Rosen (1974) and Roback (1982). This model assumes that in equilibrium there are no utility gains derived from moving locations. Hence, any change in amenities (or in how they are valued) will lead to population movement as any location offering extra-normal utility will experience in-migration until wages fall or rents rise sufficiently to eliminate the utility differential. While the value of amenities is crucial for determining the spatial allocation of the population, it is typically difficult to estimate as there are many unobserved factors that covary with both any considered amenity, and house prices and wages.[1] For this reason, most papers in this literature rely on natural experiments that exogenously change the value of amenities without directly affecting wages and rents (e.g. Albouy et al. 2014; Chay and Greenstone 2005).[2]

In this paper, we contribute to the subset of this literature that focuses on differences in local laws as a type of amenity (Malani 2008).[3] Specifically, we examine the amenity value of legalized marijuana by analyzing the impact of marijuana legalization on migration to Colorado. Colorado is the pioneering state in this area having legalized medical marijuana in

[1] For example, people living on smaller islands typically live close to the coast but also have a more constrained housing supply and less jobs from which to choose.
[2] A recent exception is Albouy and Stuart (2014) which directly estimates a parametrized version of the Rosen-Roback general equilibrium model. There are also a large number of descriptive papers looking at the relationship between local amenities and migrant settlement decisions, e.g. Rodríguez-Pose and Ketterer (2012).
[3] For example, Hellinger and Encinosa (2003) examine how laws that limit malpractice awards affect the location decisions of physicians while Young et al. (2016) examine how state tax laws on millionaires affect their migration decisions.

2000 and recreational marijuana in 2012. We test whether potential migrants to Colorado view legalized marijuana as a positive or negative local amenity.

We do this by using the synthetic control methodology, as developed in Abadie and Gardeazabal (2003) to examine in- and out-migration to/from Colorado versus migration to/from counterfactual versions of Colorado that have not legalized marijuana. This method chooses the optimal combination of donor units (in our case, states that have not legalized marijuana as of 2017) that match both migration patterns and other chosen covariates (in our case, population, income, employment rates, occupational composition and rents) in Colorado prior to marijuana legalization. We can then directly compare outcomes in Colorado after marijuana legalization to those in the optimal counterfactual version of Colorado. Unlike a traditional difference-in-differences approach, here the 'control' group is chosen by an algorithm as opposed to potentially arbitrarily by the researcher and it is not necessary to have parallel trends in counterfactual outcomes between the treated unit (i.e. Colorado) and the defined control group.[4]

We find strong evidence that potential migrants view legalized marijuana as a positive amenity with in-migration significantly higher in Colorado compared with synthetic-Colorado after the writing of the Ogden memo in October 2009 that effectively allowed state laws already in place to be activated, and additionally after marijuana was legalized in 2013 for recreational use. From 2005 – 2009, on average, 187,600 people migrated to Colorado in each year. Between 2010 and 2013, in-migration increased by 20,760 people per year (a 11.0 percent increase) in Colorado compared with synthetic-Colorado. After full legalization in 2013, in-migration further increased by 15,470 people per year (an additional 8.2 percent increase).

When we employ permutation methods to assess the statistical likelihood of our results given our sample, we find that Colorado is a clear and significant outlier.[5] We find no evidence for significant changes in out-migration from Colorado relative to synthetic-Colorado suggesting that marijuana legalization did not change the equilibrium for individuals already living in the state. In total, 155,500 more people moved to Colorado than predicted based on migration into synthetic-Colorado after the signing of the Ogden memo. Given that we find no impact on out-

[4] The synthetic control methodology is ideal for examining the impact of law changes in a single geographical unit (e.g. state) which can be seen by the recent explosion of papers using this approach (e.g. Abadie et al. 2010; Bohn et al. 2014; Jones and Marinescu 2018)

[5] Our results are robust to how the synthetic weights are chosen and to further controlling for state and time fixed effects in a weighted difference-in-differences framework.

migration, this implies that marijuana legalization increased Colorado's population by 3.2 percent as of 2015.

Our findings are consistent with evidence that around 60 percent of Americans support marijuana legalization (Pew Research Center 2018) and anecdotal evidence that states that have legalized marijuana have attracted migrants (The Hemp Connoisseur 2014). They are also consistent with most previous research that has in general found positive effects of legalization, such as reductions in youth suicide, traffic accidents and crime (see above for citations). Furthermore, as legal marijuana is taxed and raises significant revenues for states (Business Insider 2018), our findings are also consistent with individuals being attracted to states with increasing revenues.

Given that Colorado was a first-mover state, it is unclear whether later-mover states will attract population flows to the same extent, but overall our findings suggest that the widespread movement to legalize marijuana in the US has had consequences for the spatial equilibrium of the US population. Depending on the composition of the individuals that are attracted to states that are earlier legalizers of marijuana, there could also be flow-on consequences for marijuana consumption, direct and indirect tax collection and the social welfare system. In line with the Rosen and Roback model, there should also be either a decline in wages and/or an increase in housing costs in Colorado as a result of the increased in-migration induced by marijuana legalization.

Our paper proceeds as follows: in the next section, we provide background on marijuana legalization in general and the situation in Colorado. In section 3, we discuss the synthetic control method and the data we use in our analysis. In section 4, we present our results and robustness checks. We then conclude in section 5.

2. Background

2.1 Marijuana Policy in Colorado

On November 7, 2000, Amendment 20 (Medical Marijuana Law) was approved via ballot initiative by Colorado's constituents. Starting January 1, 2011, individuals with debilitating medical conditions could gain access to marijuana by getting a certificate from a physician certifying their illness. Both patients and primary caregivers were required to register with the Colorado Department of Public Health and Environment and were allowed to possess up to two ounces (57 g) of marijuana and cultivate up to six marijuana plants, with only three of

them being mature at the same time. However, these activities remained illegal under the federal Controlled Substances Act of 1970, which classifies marijuana as a Schedule 1 drug, and hence marijuana was only available from plants grown in non-commercial, home settings and the number of medical users remained relatively small (Eddy 2010).

A large change in access to medical marijuana occurred October 19, 2009 when Attorney General Eric Holder announced formal guidelines for federal prosecutors in states that had enacted laws authorizing the use of marijuana for medical purposes. In what is widely known at the 'Ogden memo', the Justice Department clarified that in states like Colorado, "the federal government would not prosecute anyone operating in clear and unambiguous compliance with the states' marijuana laws" (Miron, 2014). Colorado state law was quickly changed to permit commercial production and distribution of medical marijuana. The number of registrants grew rapidly from 4,819 in December 2008 to 115,467 in December 2014 (Ghosh 2015).

On November 6, 2012, Colorado's constituents approved Amendment 64 via ballot initiative by a slight margin, legalizing marijuana use for recreational purposes. This new amendment authorized any individual, age 21 or over, to purchase and possess up to one ounce (28 g) of marijuana and cultivate six marijuana plants. For non-Colorado residents, a one-quarter of an ounce (7g) purchasing limit was placed aimed at limiting the transportation of large quantities of marijuana to other states (Miron, 2014). Under this new amendment, medical marijuana provisions remained unaffected. The first dispensaries selling marijuana for recreational use opened in 2014 so up until that point there was little direct impact of the amendment except that marijuana could now be grown at home for purely recreational usage.

2.2 Marijuana Policy in the Rest of the US

States can be divided into three main categories in terms of how they regulate the selling of marijuana: i) states in which all sales are illegal; ii) states in which selling is legal only for medical purposes; and iii) states in which selling is also legal for recreational purposes.[6] Laws regarding possession are more nuanced and have greater variation across states. In order to assess the impact of marijuana legalization in Colorado using the synthetic control method, a donor pool of states must be used to create a synthetic-Colorado, which 'looks' like Colorado in terms of pre-legalization migration levels and key covariates, but in which marijuana is not

[6] Legality of cannabis by U.S. jurisdiction, Retrieved January 24, 2017 from https://en.wikipedia.org/wiki/Legality_of_cannabis_by_U.S._jurisdiction#By_state.

legal. Hence, we only include in our donor pool the 20 states where in 2017 selling marijuana is still illegal for all purposes (see Table 1 for the list of donor pool states). This ensures that no state in synthetic-Colorado is directly affected by marijuana legalization.

3. Methodology and Data

3.1 The Synthetic Control Method

We rely on the synthetic control method, as developed in Abadie and Gardeazabal (2003), to examine the impact of marijuana legalization on migration to/from Colorado. This approach compares outcomes for Colorado to those for a synthetic-Colorado created as a weighted combination of other US states chosen to best reproduce the characteristics of Colorado before marijuana legalization. Let J be the number of donor states (the 20 US states in the donor pool), **W** is a $(J \times 1)$ vector of nonnegative weights such that $w_1 + \ldots w_j = 1$ and $w_j \geq 0$ $(j = 1, 2 \ldots J)$ where $w_j (j = 1, \ldots, J)$ is the weight of state j in the synthetic-Colorado, $\boldsymbol{X_1}$ is a $(K \times 1)$ vector of values of K migration predictors for Colorado before legalization of marijuana, and $\boldsymbol{X_0}$ is a $(K \times J)$ matrix with all the migration predictors for all possible control states J.

The synthetic control method chooses $\boldsymbol{W}^*$, which is the vector of weights that determines the best control region for Colorado by minimizing $(\boldsymbol{X_1} - \boldsymbol{X_0 W})' \boldsymbol{V} (\boldsymbol{X_1} - \boldsymbol{X_0 W})$ subject to $w_1 + \ldots w_j = 1$ and $w_j \geq 0$ $(j = 1,2 \ldots J)$ where $\boldsymbol{V}$ is a diagonal matrix with non-negative components where the values represent the relative importance of each migration predictor. The optimal **V** is chosen to best reproduce the path of the outcome variable (i.e. migration levels) during the pre-treatment period (Abadie and Gardeazabal 2003). More formally, let $\boldsymbol{Z_1}$ be a $(T_p \times 1)$ vector containing the values of the outcome variable in the pre-treatment period (T_p is the number of pre-treatment periods) and $\boldsymbol{Z_0}$ a $(T_p \times J)$ matrix containing the values of the same variable for the J potential donor regions. Then

$$\boldsymbol{V}^* = \underset{\boldsymbol{V} \in \mathcal{V}}{\operatorname{argmin}} (\boldsymbol{Z_1} - \boldsymbol{Z_0 W}^* (\boldsymbol{V}))' (\boldsymbol{Z_1} - \boldsymbol{Z_0 W}^* (\boldsymbol{V})) \quad (1)$$

where $\mathcal{V}$ is the set of all nonnegative diagonal $(K \times K)$ matrices. Hence, the weights for the synthetic control depend directly on the relative importance given to each predictor of pre-treatment migration. Alternatively, weights can be chosen only using information on the pre-treatment outcomes which simplifies the calculation of the optimal weighting matrix to: $(\boldsymbol{Z_1} - \boldsymbol{Z_0 W})' (\boldsymbol{Z_1} - \boldsymbol{Z_0 W})$ subject to $w_1 + \ldots w_j = 1$ and $w_j \geq 0$ $(j = 1,2 \ldots J)$.

Once the optimal weights minimizing the difference in outcomes for the pretreatment period have been established, the effect of marijuana legalization can be calculated by examining the differences in outcomes after legalization between Colorado and synthetic-Colorado. More formally,

$$\mathfrak{m}_t = Y_{it}^I - Y_{it}^N \tag{2}$$

where $\mathfrak{m}$ is the policy effect for Colorado at time t calcuated as the difference in the outcome for Colorado, Y_{it}^I , and the generated outcome for synthetic-Colorado,

$$Y_{it}^N = \sum_{\substack{j=1 \\ j \neq i}}^{J} w_j Y_{jt}^N \,, \tag{3}$$

which is the combination of observed outcomes for the states in the donor pool, using the optimal weights calculated with the synthetic control method.[7]

Although the synthetic control method always generates the 'best' match in the pre-treatment period, the constraint that the weights must be non-negative means that it is not guaranteed to fit pre-treatment trends well. This depends on whether or not $\mathbf{Z_1}$ lies within the convex hull of the $\mathbf{Z_0}$ vector of the control states.[8] Following Abadie et al. (2010), we judge the quality of the match by estimating the mean-square prediction error (MSPE) for pre-intervention outcomes, i.e. the square root of (1), for our main estimate and for each of our placebo estimates described below. We then rank the fit across all placebos.

To calculate the significance of our estimates, we implement a permutation method suggested by Abadie et al. (2015), comparing our synthetic control estimate to a distribution of placebo estimates. Formally, we implement the above synthetic control procedure for all 20 states in our donor pool and repeat this exercise as if the treatment year occurred in each year of the post-treatment time period (from 2010 to 2015) for a total of 120 placebo experiments. We define $\hat{m}_{jt}$ as the estimate for state j with placebo treatment year *t*. We then conduct a two-tailed test of the null hypothesis of no effect in Colorado by comparing the true treatment effect to the empirical distribution of placebo estimates. Specifically, our placebo "p-value" is

[7] Abadie et al. (2010) provide more details about the synthetic control methodology. We use the "Synth" package in R to implement the approach on our data (Abadie et al. 2011). The policy effect can also be estimated in a more traditional difference-in-differences model where state and time fixed effects are included and the synthetic control weights are used to generate the correct control group. This has the advantage that aggregate macroeconomic effects are controlled for via the time fixed effects but with the additional assumption that there must be parallel trends in counterfactual outcomes between the treatment (i.e. Colorado) and control group (i.e. synthetic-Colorado).

[8] In other words, if the treated state is an outlier in terms of the outcome in the pre-treatment period, it will not be possible to create a good match from a pool of other states.

defined as the proportion of estimates where the treatment effect in Colorado is smaller in absolute value than the placebo estimate.

We can also calculate confidence intervals by inverting the permutation test. Specifically, as suggested in Firpo and Possebom (2017), we re-run the permutation method where the post-treatment outcome for Colorado is transformed by a particular α^*. The 90% confidence interval is then defined at the set of α^* where we cannot reject the null hypothesis of Colorado being significantly different than more than 90% of placebo treatments.

3.2 Data

Our main data source is the American Community Survey (ACS). Our outcome variables are calculated using the State-to-State migration tables generated using the ACS and available in the US Census Bureau's online database. These tables indicate how many individuals changed residence within the US during the previous year, and specify the origin and destination state. We aggregated the data to calculate both the total inflow into and the total outflow out of every state in every year from 2005 to 2015. These are the two dependent variables in our analysis.[9]

We consider a number of predictors of migration levels. Also from the ACS, we control at the state-level for the average total population, median income, labor force participation rate, unemployment rate, and occupational composition (at the one-digit level) in the pre-treatment period. We also control for per-capita state level tax revenues in the pre-treatment period from the Annual Survey of State Government Tax Collections, where taxes are defined as all compulsory contributions exacted by a government for public purposes, except employer and employee assessments for retirement and social insurance purposes. And finally, we control for average monthly housing costs in the pre-treatment period using the price of a vacant 2-bedroom rental unit at the 45th percentile of the Metropolitan Statistical Area (MSA) distribution as measured in the Department of Housing and Urban Development Fair Market Rent series (Saiz 2007).[10] As we only have 20 states in our donor pool, we can only control for key covariates that are potentially related to trends in migration. As a robustness check, we

[9] We examined migration in levels, logs and as a percentage of the previous year's population. We get the best fit in terms of RMSE in the pre-treatment period when we focus on migration levels so present those results in the paper. Our findings are qualitatively similar if we instead examine logs or rates. This is also the most common way used in the literature to measure internal migration (Molloy et al. 2011).

[10] We generate state level data by averaging all MSAs belonging to the same state ignoring those that belong to multiple states.

also do the synthetic control match without including covariates, and as will be shown below, get similar results.

4. Results

4.1 Synthetic Control Weights and Match Quality

As discussed above, we have a donor pool of 20 states in which the sale of marijuana is fully illegal as of 2017 for which to generate a synthetic-Colorado. As marijuana was not widely available in Colorado (or any states) until the writing of the Ogden memo in October 2009, we treat 2010-2015 as the treatment period in our analysis and 2005-2009 as the pre-treatment period.[11] Hence, our synthetic control weights will be calculated to create a synthetic-Colorado that best matches in- and out-migration levels in the 2005-2009 period as well as the covariates discussed in the previous section.

Table 1 presents the results from this exercise done separately for in-migration and out-migration. For in-migration, synthetic-Colorado is a composition of 13 states from the donor pool, with Virginia and Pennsylvania being the largest contributors with 28.7% and 28.0% weights, respectively, and Utah, Idaho and Missouri being the other large contributors. Virginia and Pennsylvania are both larger states with similar striking urban/rural divides as in Colorado while Utah, Idaho and Missouri are in reasonable close geographic proximity. A similar, but smaller number of states are chosen to create synthetic-Colorado when we are looking at in-migration. The largest change is that South Dakota, another geographic proximate state, replaces Utah among the large contributors.

Table 2 shows how the two weighted synthetic-Colorados look in terms of matching the real Colorado in the pre-treatment period in terms of outcomes and covariates. Most importantly, there is a nearly perfect match in terms of the two outcomes variables even though the donor pool candidates have in general less migration than Colorado. Synthetic-Colorado is generally a bit larger in population than real Colorado both otherwise looks pretty similar. The MSPE shows that we do an excellent job fitting the pre-treatment in-migration and out-migration trends for Colorado and that the fit is in the middle of the distribution in terms of how well we can fit pre-treatment outcomes for all the placebo interventions.

[11] Zambiasi (2017) explores other definitions of the treatment period and discusses why this one makes the most sense. Examining the raw data on migration into Colorado, one also observes little change until 2010 (see Figure 1).

4.2 Main Results

Figures 1 (in-migration) and 2 (out-migration) present our main results. In the top panel of each figure, we graph the outcome for Colorado (the solid line labelled treated) and for synthetic-Colorado (the dashed line labelled synthetic) created as described above. In the bottom panel of each figure, we show the difference over the whole sample period between real Colorado and synthetic-Colorado (the heavy black line) and then the difference between each placebo and synthetic treatment for 108 of 120 possible state/year combinations (the lighter lines).[12] The vertical dashed lines indicate 2010, the year that medical marijuana became widely available and 2014, the year that recreational marijuana became widely available.

Examining the pre-treatment period in both Figure 1 and 2 gives another indication of the quality of our synthetic control estimates. In the five years prior to medical marijuana being readily available, synthetic-Colorado and real Colorado have nearly identical in- and out-migration levels in all years and the general trends in the two 'states' are similar. While this is somewhat be design, recall that the synthetic control estimator attempts to match average outcomes in the pre-treatment period, hence there is no guarantee that outcomes in the real and synthetic states will follow the same trend or be similar in all pre-treatment years. Hence, this finding is a strong indicator that the synthetic control approach is applicable for our research question.

Comparing real Colorado to synthetic-Colorado in Figure 1 reveals that, once medical marijuana became widely available after the writing of the Ogden memo in October 2009, in-migration to Colorado increased by a large amount relative to in-migration to synthetic-Colorado. Large differences between the two are already apparent in 2011 and appear to get larger with each subsequent year. The lower panel shows that the difference found between real Colorado and synthetic-Colorado is larger than the difference found for all other placebo treatments. While we will present the formal statistics later in the paper, this clearly shows that in-migration to Colorado is a clear and significant outlier starting in 2011. We know of no other Colorado-specific changes that could have attracted additional migrants starting at exactly that point in time. On the other hand, it is clear in Figure 2 that increased availability

[12] As recommended by Abadie et al. (2010), we drop states/years from the bottom panel where the MSPE is more than five times that for the actual treatment indicating that we do a very poor job of matching for these states in the pre-treatment period. In practice, this drops all estimates for Florida and Texas (six for each state) and no other estimates. Each point on each lighter line shows the results from a placebo experiment hence there is one line per state.

of medical marijuana had no impact on out-migration from Colorado as out-migration is nearly identical for real Colorado and synthetic-Colorado in the entire post-treatment period.

In Table 3, we present the treatment effects illustrates in Figures 1 and 2 along with the p-value and confidence interval calculated for each estimate using the permutation method described in Section 3. We calculate treatment effects separately for each year after the Ogden memo was written and for two combined time periods, 2010-2013 when medical marijuana was widely available and 2014-2015 when recreational marijuana was widely available.

Panel A directly matches to the effects illustrated in Figure 1 for out-migration. Starting in 2011, there is a statistically significant increase in migration to Colorado. Between 2011 and 2013, between 21,400 and 30,500 extra people migrated to Colorado because of access to medical marijuana. In 2014 and 2015, an extra 35,500 to 36,900 people migrated to Colorado because of access to recreational marijuana. In the 2005 – 2009 period, Colorado averaged 188,000 migrants per year hence marijuana legalization increased in-migration by between 11.4 to 19.7 percent in each year since 2011. In total, 155,500 more people moved to Colorado than predicted based on migration into synthetic-Colorado after the signing of the Ogden memo. Given that we find no impact on out-migration, this implies that marijuana legalization increased Colorado's population by 3.2 percent as of 2015.

In Panel B, we present alternative estimates derived from a weighted difference-in-differences framework. Only data on the outcome variable is used here but both state and year fixed effects are included in the model along with interactions between post-treatment indicator and an indicator for Colorado. The data for each state is then weighted by the derived synthetic control weight for that state. This approach has the additional advantage that any macroeconomic effects on migration in all states will now be controlled for, but requires the additional assumption that macroeconomic effects are the same for all states.[13] We now find qualitatively similar but slight smaller estimates of the impact of marijuana legalization on migration to Colorado. This is either because migration was increasing, on average, in US states in the 2010-2015 period and the synthetic control estimator does not capture this or because synthetic-Colorado and real Colorado are not following parallel trends. It is not possible to directly test which explanation is correct here, but given the similarity of the results, we view this as a robustness check of our findings.

[13] This is equivalent to the typically discussed parallel trends assumption required for unbiased estimation of difference-in-differences models. The standard synthetic control estimator does not require this.

In Panel C and D, we present similar estimates for out-migration. Confirming the graphical analysis in Figure 2, we find no evidence that legalization of marijuana has impacted out-migration from Colorado in any years following the Ogden memo. Our estimates are precise enough to rule out at anything other than very small impacts. This suggests that marijuana legalization had no impact on the equilibrium for individuals already living in the state.

4.3 Robustness Checks

Our final analysis examines the robustness of our findings to two choices made during the process of generating the synthetic control version of Colorado. First, as the correct choice of covariates is unclear and we only have nineteen degrees of freedom to work with, we examine whether our results are robustness to excluding covariates entirely and just matching on the outcome variable in the pre-treatment period. Second, as pointed out in Kaul et al. (2015), if one believes that the covariates are particularly important for explaining the outcome variable then one is better off not controlling for the outcome in the entire pre-treatment period. In fact, it is optimal just to control for the outcome in a short window prior to treatment. Since we already have a short pre-treatment period, we examine whether our results are robust to only including migration in 2009 along with covariates when generating the synthetic control version of Colorado.

Table 4 presents the results from this exercise. In both cases, our main findings are qualitatively unaffected. When we do not use covariates when deriving synthetic-Colorado, we find a slightly larger significant impact of marijuana legalization on in-migration, but cannot reject that the impacts are the same as in our main specification. On the other hand, when we only use information only for 2009 when deriving synthetic-Colorado, our estimated impacts of in-migration are slightly smaller. Again, they are not statistically different than our main results. In fact, most of our estimates are no longer statistically significant from zero as just matching on information on 2009 while generating synthetic-Colorado reduces the precision of the empirical approach.

5. Conclusion

In this paper, we examine the amenity value of legalized marijuana by analyzing the impact of marijuana legalization on migration to Colorado. Colorado is the pioneering state in this area having legalized medical marijuana in 2000 and recreational marijuana in 2012. We test whether potential migrants to Colorado view legalized marijuana as a positive or negative local amenity. We do this by using the synthetic control methodology to examine in- and out-

migration to/from Colorado versus migration to/from counterfactual versions of Colorado that have not legalized marijuana.

We find strong evidence that potential migrants view legalized marijuana as a positive amenity with in-migration significantly higher in Colorado compared with synthetic-Colorado after the writing of the Ogden memo in October 2009 that effectively allowed state laws already in place to be activated, and additionally after marijuana was legalized in 2013 for recreational use. From 2005 – 2009, on average, 187,600 people migrated to Colorado in each year. Between 2010 and 2013, in-migration increased by 20,760 people per year (a 11.0 percent increase) in Colorado compared with synthetic-Colorado. After full legalization in 2013, in-migration further increased by 15,470 people per year (an additional 8.2 percent increase).

When we employ permutation methods to assess the statistical likelihood of our results given our sample, we find that Colorado is a clear and significant outlier. We find no evidence for significant changes in out-migration from Colorado relative to synthetic-Colorado suggesting that marijuana legalization did not change the equilibrium for individuals already living in the state. In total, 155,500 more people moved to Colorado than predicted based on migration into synthetic-Colorado after the signing of the Ogden memo. Given that we find no impact on out-migration, this implies that marijuana legalization increased Colorado's population by 3.2 percent by 2015.

Given that Colorado was a first-mover state, it is unclear whether later-mover states will attract population flows to the same extent, but overall our findings suggest that the widespread movement to legalize marijuana in the US has had consequences for the spatial equilibrium of the US population. Depending on the composition of the individuals that are attracted to states that are earlier legalizers of marijuana, there could also be flow-on consequences for marijuana consumption, direct and indirect tax collection and the social welfare system. In line with the Rosen and Roback model, there should also be either a decline in wages and/or an increase in housing costs in Colorado as a result of the increased in-migration induced by marijuana legalization. Future research could use individual level data from the ACS to explore heterogeneous effects and model the general equilibrium consequences of Marijuana legalization.

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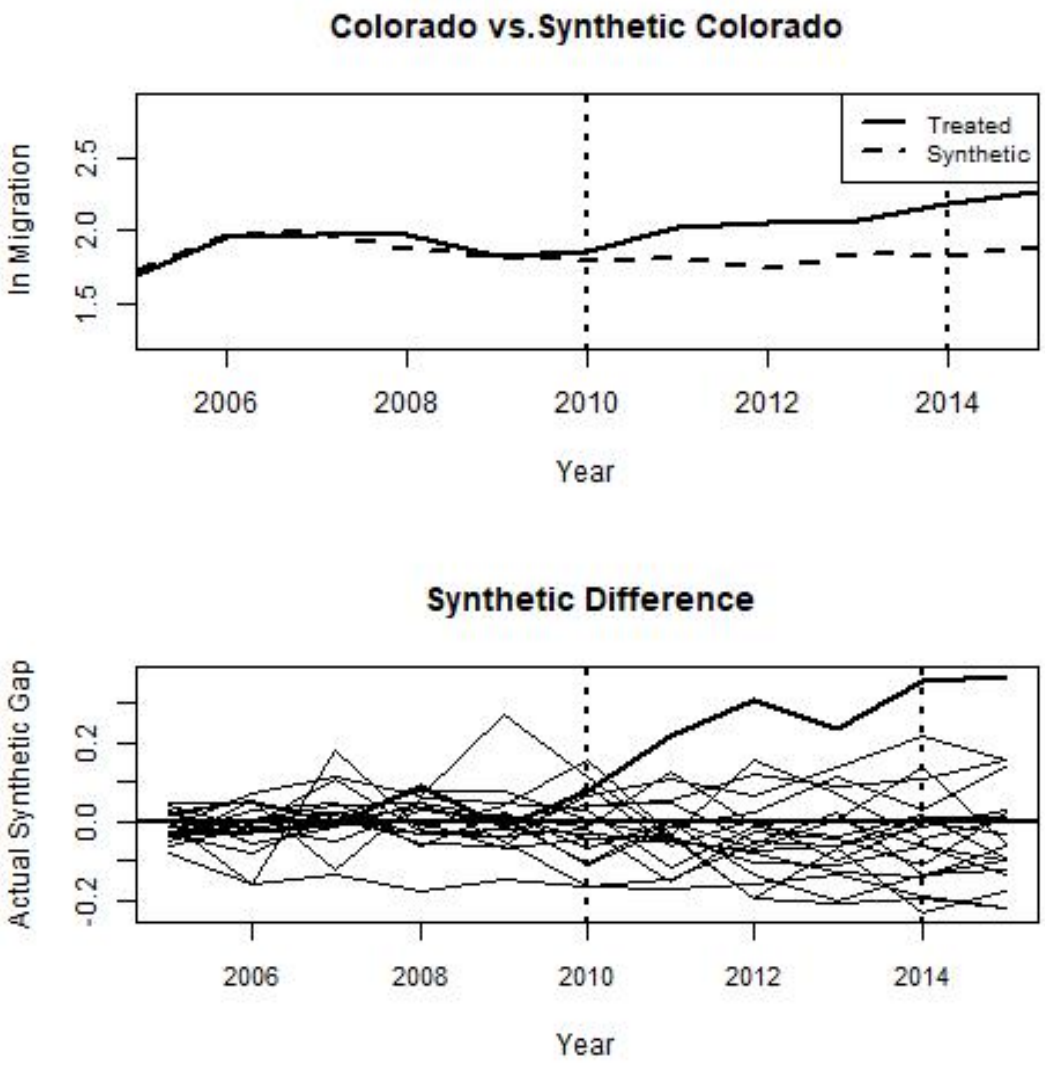
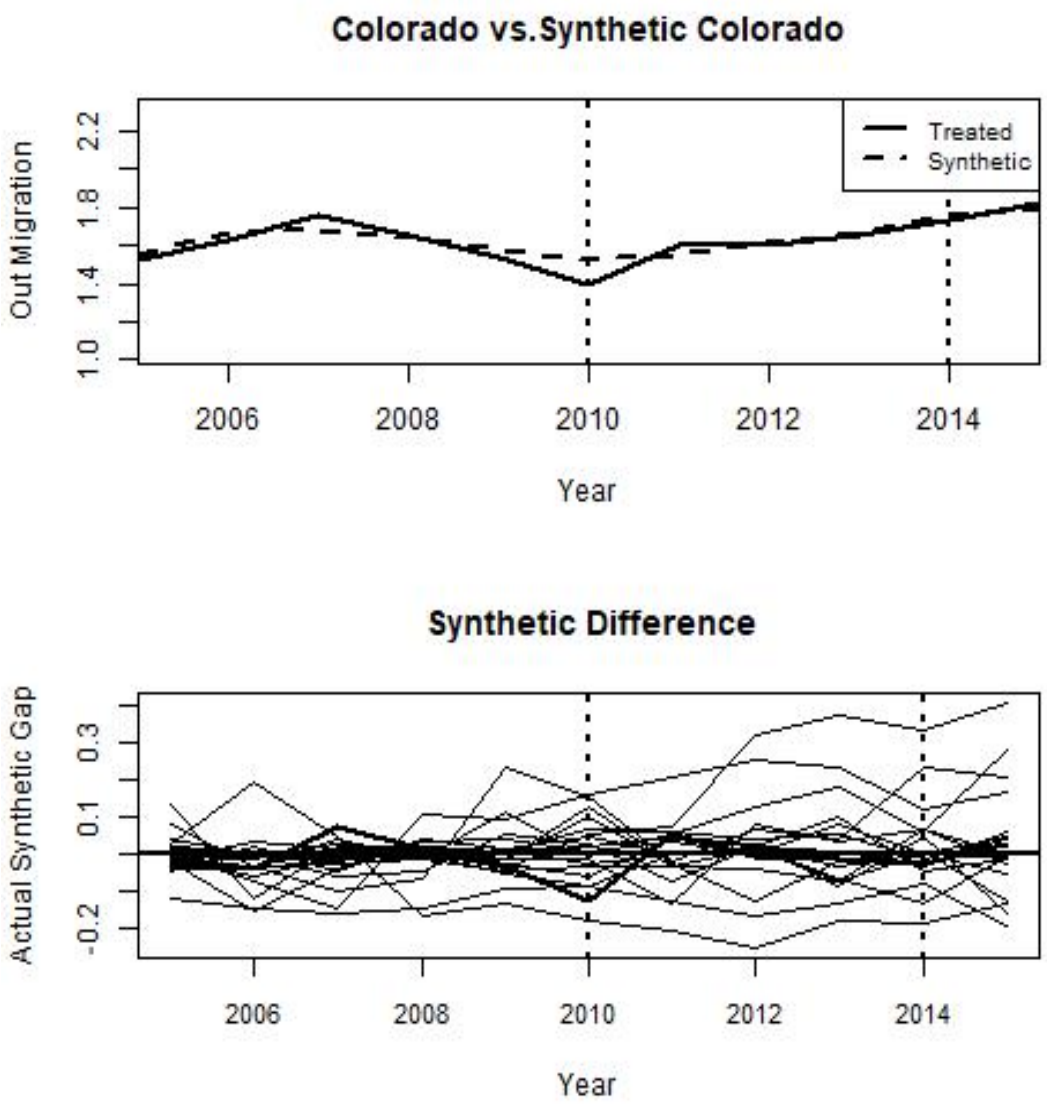
Figure 1: Impact of Marijuana Legalization on In-Migration to Colorado



Notes: The top panel plots the synthetic control estimates of in-migration in 100,000s for Colorado from 2005 to 2015. The solid line plots the actual in-migration level in Colorado, while the dotted line plots the synthetic control estimate. The vertical dashed lines indicate 2010, the year that medicial marijuana became widely available and 2014, the year that recreational marijuana became widely available. The bottom panels plots the results of a permutation test of the significance of the difference between Colorado and synthetic Colorado. The solid dark line plots the difference for Colorado using the true introduction of the treatment in 2010. The lighter lines plot the difference using other states and treatment years. We drop states/years where the RMSE is more than five times that for the actual treatment indicating that we do a very poor job of matching for these states in the pre-treatment period.

Figure 2: Impact of Marijuana Legalization on Out-Migration from Colorado



Notes: The top panel plots the synthetic control estimates of out-migration in 100,000s for Colorado from 2005 to 2015. The solid line plots the actual out-migration level in Colorado, while the dotted line plots the synthetic control estimate. The vertical dashed lines indicate 2010, the year that medicial marijuana became widely available and 2014, the year that recreational marijuana became widely available. The bottom panels plots the results of a permutation test of the significance of the difference between Colorado and synthetic Colorado. The solid dark line plots the difference for Colorado using the true introduction of the treatment in 2010. The lighter lines plot the difference using other states and treatment years. We drop states/years where the RMSE is more than five times that for the actual treatment indicating that we do a very poor job of matching for these states in the pre-treatment period.

Table 1: State Weights for Synthetic Colorado

State	In-Migration	Out-Migration
Alabama	0	0
Florida	0	0.018
Idaho	0.104	0.196
Iowa	0.001	0
Kansas	0.023	0
Mississippi	0	0
Missouri	0.150	0.021
Nebraska	0.015	0
North Dakota	0.001	0
Oklahoma	0	0
Pennsylvania	0.280	0.297
South Carolina	0	0
South Dakota	0.003	0.178
Tennessee	0	0
Texas	0.001	0
Utah	0.132	0
Virginia	0.287	0.288
West Virginia	0	0
Wisconsin	0.001	0
Wyoming	0.001	0

Note: This table reports all states in the donor poll and the weights chosen using the method described in Section 3 to construct a synthetic control for Colorado for in-migration and out-migration outcomes.

Table 2: Pre-Treatment Covariate Balance

	Colorado	All Donor Pool States	In-Migration Match	Out-Migration Match
In-Migration (100,000s)	1.88	1.50	1.87	
Out-Migration (100,000s)	1.62	1.32		1.62
Population (100,000s)	48.4	55.5	72.2	68.2
Median Income (1,000s)	65.1	52.7	59.2	57.8
House Rent Per Month	725	565	627	622
Per-Capita Tax Revenues (1,000s)	3.34	4.38	4.30	4.19
In Labor Force	0.703	0.658	0.664	0.663
Employed	0.933	0.933	0.933	0.934
Unemployed	0.058	0.059	0.057	0.055
Armed Forces	0.007	0.005	0.007	0.007
Management and Professional Occs	0.351	0.303	0.329	0.330
Service Occupations	0.150	0.152	0.147	0.149
Sales and Office Occupations	0.237	0.237	0.240	0.235
Resources and Construction Occs	0.106	0.108	0.099	0.103
Production and Transportation Occs	0.088	0.132	0.119	0.118
Pre-Period Mean-Squared Predication Error			0.033	0.037
Pre-Period MSPE Percentile			45th	45th

Note: Table reports average value of variables during the pre-treatment period for Colorado, all donor states and the synthetic control constructed using the method in Section 3. Columns (3) - (4) differ in the outcome matched on. The mean squared prediction error (MSPE) is calculated using all pre-treatment data and the percentile is based on a comparison among all placebo estimates.

Table 3: Impact of Marijuana Legalization on Migration to/from Colorado

Year	2010	2011	2012	2013	2014	2015	2010-2013	2014-2015
Panel A: Impact on In-Migration (100,000s), Colorado compared with Synthetic Colorado								
Treatment Effect	0.075	0.214	0.306	0.236	0.355	0.369	0.208	0.362
P-value	0.481	0.037	0.000	0.000	0.000	0.000	0.037	0.000
95% CI	[0.031, 0.107]	[0.063, 0.215]	[0.095, 0.323]	[0.127, 0.431]	[0.159, 0.539]	[0.191, 0.646]	[0.111, 0.377]	[0.175, 0.593]
Panel B: Impact on In-Migration (100,000s), Weighted Difference-in-Differences Estimates with State and Year Fixed Effects								
Treatment Effect	0.072	0.199	0.263	0.160	0.261	0.249	0.205	0.269
P-value	0.417	0.037	0.019	0.102	0.019	0.019	0.019	0.000
Panel C: Impact on Out-Migration (100,000s), Colorado compared with Synthetic Colorado								
Treatment Effect	-0.126	0.055	-0.009	-0.011	-0.024	0.029	-0.023	0.003
P-value	1.000	0.509	1.000	1.000	1.000	0.685	1.000	0.944
95% CI	[-0.073, 0.061]	[-0.146, 0.122]	[-0.219, 0.183]	[-0.292, 0.244]	[-0.365, 0.305]	[-0.438, 0.366]	[-0.255, 0.214]	[-0.401, 0.336]
Panel D: Impact on Out-Migration (100,000s), Weighted Difference-in-Differences Estimates with State and Year Fixed Effects								
Treatment Effect	-0.125	0.077	0.003	0.000	-0.013	0.041	-0.021	0.014
P-value	1.000	0.306	0.944	1.000	1.000	0.565	1.000	0.528
Placebos	108	108	108	108	108	108	108	108

Note: This table presents estimates of effect of access to legalized marijuana on migration to/from Colorado using the synthetic control method outlined in Section 3. In Panel A and C, the treatment effect calculated by comparing Colorado to synthetic Colorado is shown for each post-treatment year and for the average of 2010-2013 and 2014-2015. In Panel B and D, treatment effects are from weighted difference-in-differences models that also control for state and year fixed effects. All p-values and confidence intervals are constructed using the permutation test described in Section 3.

Table 4: Robustness Checks

Year	2010	2011	2012	2013	2014	2015	2010-2013	2014-2015
Panel A: Impact on In-Migration (100,000s), No Covariates Used When Deriving Weights								
Treatment Effect	0.144	0.235	0.252	0.206	0.300	0.321	0.210	0.311
P-value	0.139	0.000	0.000	0.019	0.000	0.000	0.019	0.000
Panel B: Impact on In-Migration (100,000s), Only 2009 Outcome Used When Deriving Weights								
Treatment Effect	0.083	0.177	0.209	0.153	0.247	0.273	0.156	0.260
P-value	0.509	0.204	0.139	0.241	0.093	0.083	0.241	0.093
Panel C: Impact on Out-Migration (100,000s), No Covariates Used When Deriving Weights								
Treatment Effect	-0.114	0.068	0.060	0.095	0.115	0.169	0.027	0.142
P-value	1.000	0.370	0.417	0.231	0.167	0.074	0.648	0.130
Panel D: Impact on Out-Migration (100,000s), Only 2009 Outcome Used When Deriving Weights								
Treatment Effect	-0.126	0.057	0.049	0.084	0.101	0.155	0.016	0.128
P-value	1.000	0.481	0.546	0.296	0.222	0.102	0.806	0.120
Placebos	108	108	108	108	108	108	108	108

Note: This table presents estimates of effect of access to legalized marijuana on migration to/from Colorado using the synthetic control method outlined in Section 3. More restricted sets of covariates are used when generating the synthetic control weights in these specifications. All p-values are constructed using the permutation test described in Section 3.