Green Acres? Cannabis agriculture, formalization, and rural land values in Northern California

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Abstract

Cannabis legalization has progressed rapidly in the last decade. Unlike previous efforts, which concentrated on the retailing and possession of cannabis, recent changes include formalization of the entire cannabis supply chain. These reforms will have important consequences, particularly for regions in which significant cannabis production for the gray or black market already exists. We study the relationship between land prices and cannabis production in perhaps the largest cannabis producing area in the United States: Humboldt County in Northern California. We explore this link in two ways. First, we connect data on the location of cannabis cultivation to land sales over the previous decade and find a generally positive relationship between cannabis farming and the sale price of nearby land. That finding supports anecdotal perceptions of a positive link between the real estate market and cannabis, and suggests that its higher potential net return outweighs potentially negative externalities associated with the production of an illicit or quasi-licit good. Second, we find that the enactment of a permitting process that allowed land owners meeting specific agro-ecological criteria to participate in the legalized cannabis supply chain led to a sharp increase in land prices of eligible properties. That result suggests suppliers in a region known producing largely for the illegal market perceived significant positive future returns from the legal supply chain, despite the existence of potentially costly regulatory and tax burdens.

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JEL: Q15; E26

Introduction

Cannabis production is an increasingly important rural land use (Short Gianotti et al. 2017; Németh and Ross 2014). Now legal as either medicine or for recreational purposes in 40 states, cannabis is a multi-billion dollar industry and production often takes place in rural areas alongside traditional land uses (Arcview Market Research 2014).[1] While cannabis has operated in a quasi-legal space since California legalized medicinal use in 1996, early regulations typically focused primarily on use of cannabis. The most recent wave of legal reform, however, has significantly impacted patterns of cannabis production by attempting to formalize the entire cannabis supply chain, including cannabis production, distribution, sale and use.

Legalization has important consequences for rural communities. While the overall footprint of cannabis production is small, it can have outsized economic and social impacts. In many cases, revenue from cannabis far outstrips other crops on a per acre basis, making it a focal point of rural economic development. At the same time, neighbors to cannabis farms have often raised objections related to safety, noise, smell, environmental damage and the overall stigma of a nearby illicit business.[2] For example, A survey of rural landowners in Humboldt County - one of the top cannabis producing counties in the country - found significant negative externalities from cannabis production: 65% of respondents reported that cannabis had been grow without their permission on their property, 75% say that cannabis farmers have degraded their shared roads and 60% claim that cannabis farmers have increased the cost of labor for farm and timber production. Further, there is increasing evidence that outdoor production takes place in ecologically sensitive areas, and there are concerns about water diversion and the use of chemical inputs (Carah et al. 2015; Bauer et al. 2015; Gabriel et al. 2012).

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[1] The focus of this article is cannabis produced without regard to limits on THC, commonly referred to as marijuana. Hemp produced with a THC content below .3 percent is now fully legal in the United States, and many states permit the sale of CBD-based cannabis products that contain more THC than permitted under federal hemp regulations.

[2] These concerns have been the subject of high profile, but unsuccessful, lawsuits by neighbors of newly sanctioned cannabis businesses (Elias 2018).

The illicit nature of cannabis has meant that agricultural economists' understanding of this market has lagged, even though the value of cannabis production exceeds many traditional crops (see Sumner and Goldstien (2023) for a recent survey of economic data on legal cannabis and discussion on legalization). A particularly important area that lacks economic data is the relationship between cannabis production and land values, a subject which has long been a staple of agricultural research for other crops (Featherstone and Baker 1987). On one hand, the ability to produce cannabis should clearly increase the productive potential of land, increasing land prices. Yet cannabis grows may have strong negative externalities for traditional rural landowners, which may hold prices down for rural land not used for cannabis. Thus, the question of how cannabis liberalization impacts rural property prices deserves empirical attention.

In this article, we focus on a particular moment when policy change in Humboldt County created an ideal setting to understand the relationship between land values and cannabis production in Northern California in both the historical illicit context, as well as the current environment of formalization. Our research provides important evidence on how cannabis has traditionally impacted land prices in a region known for illegal cannabis production as well as how producers value entry into the legal supply chain, which entails considerable compliance costs and taxation. .

Humboldt County, CA, is an appealing place to study the impacts of cannabis and industry formalization on land prices. At the time of the study, it likely had the most cannabis farms in the country alongside productive and recreational rural lands (Decorte, Potter, and Bouchard 2011). Importantly, Humboldt County also has three qualities which make identifying the effects of cannabis production and formalization feasible. First, cannabis production is clustered geographically in the county creating hotspots and coldspots in production. Importantly, locations of hotspots are not based on biophysical variables related to productivity of cannabis farms, but rather on historical and cultural legacies. This allows us to credibly estimate the effect of cannabis on property prices separate from growing conditions using a standard hedonic pricing model. Second, Humboldt County set zoning restrictions for cannabis, and by doing so, created a set of parcels eligible to legally produce cannabis.

The policy provides the opportunity to credibly estimate the impact of formalization by comparing sale prices from eligible and non-eligible parcels before and after the policy change using a difference-in-differences strategy. Third, Humboldt County was the first county in California to formalize their land use plans to indicate which parcels permitted cannabis farms. At the time of the study, Humboldt County was unique from every other county in California in providing clarity as to what parcels could legally host cannabis farms. This allows us to make comparisons both within and across counties to estimate effects.

To estimate the relationship between cannabis and rural land prices we use a dataset of arms-length property transactions of rural land between 2009 and 2017, data on the location and size of cannabis farms in 2012 and 2016, and a set of rules promulgated in 2016 that delineate the eligibility of cannabis farms for entry into the legal supply chain. We also include spatial and environmental characteristics of the properties which may impact productive capacity or recreational value. We perform a suite of robustness checks that demonstrate the results are not sensitive to particular estimation choices.

We find the density of cannabis production has a positive relationship with property prices, which suggests economic returns to cannabis production in Humboldt County have outweighed disamenity effects on traditional landowners. In evaluating the impact of formalization, we find the introduction of a permit system to legally produce cannabis caused sales prices of eligible properties to nearly double relative to ineligible properties. The estimated increase suggests that a significant share of cannabis farmers and investors believe that entry into the legal system is worth the higher costs associated with legal supply chains.

We believe these results are useful beyond their understanding of the particular moment and location of this study. For one, most of the United States does not have a formal cannabis production and distribution market. Barring a major change in federal law, cannabis markets will remain disjointed for the foreseeable future, with no legal interstate and potentially limited intrastate trade. As a result, similar dynamics may prevail in other rural areas that attempt to initially define a limited entrée into formalization. Second, even as the development of formal cannabis markets in several major states continues, questions remain about the fate of black market production. Our results indicate that even in an epicenter of illicit production, some producers see sufficient excess value in legitimate production. For policymakers, that means the structure of formalization incentives matter for the decisions of producers

Background and Setting

Humboldt County is located along the Pacific coast and is considered the leading cannabis producing region in the United States, if not the world. The county is heavily forested with a mix of coniferous and hardwood forest, and pockets of open rangeland. Timber production contributes about $72 million in direct sales (Humboldt County 2015) in the county and historically has been a major center of economic activity. Due to the steep terrain and poor soils, traditional agriculture is confined to a relatively small area. Livestock, dairy, and nursery production are the largest agricultural sectors ($76, $61, and $41 million dollars in sales in 2014) and make up over 95% of all non-cannabis agricultural production by value. In comparison, the wholesale value of cannabis production is likely well over $300 million, although no official figures exist (Butsic and Brenner 2016a).[3] Estimates of the fraction of the county's economy dependent on cannabis are between 25 and 50 percent (St. George 2016). Beyond agriculture, second home ownership is also an important rural land use, and over 5% of all residences used primarily for recreation purposes, a rate double the state average.

Cannabis regulation and production

Since 1996, California has allowed the legal cultivation of cannabis for medicinal purposes, although the federal government still considers cannabis an illegal Schedule I drug. During the medicinal use era, producers supplying cannabis to others were required to be documented care givers. They could supply their crop either to individuals who have physician approval or to dispensaries, which could sell cannabis to patients. In November 2016, California voters approved an 'adult use' ballot measure legalizing the recreational use of marijuana. However, the provisions of that measure were not

[3] Based on regional production estimates in MacEwan et al. (2017) and a wholesale value share estimates from Agricultural Issues Center (2017), the value of wholesale production in California's North Coast region, which includes Humboldt, was approximately $1 billion in 2016.

implemented until 2018, after the period of our study. Full implementation of these policies is still not complete in 2020.

Under the Obama administration, federal law enforcement agencies did not strongly enforce federal cannabis laws in states permitting its use, although there is precedent for federal actions on dispensaries and growers (Zilversimt 2016). Federal law typically enforces a 5-year prison sentence for cultivation sites larger than 99 plants, hence anecdotal evidence suggests that some farmers traditionally did not exceed that number in case of federal intervention (California Normal 2016). At the time of our study there was no organized program in California to track cannabis cultivation siting, production, or sales, even in the legal market.

Detailed research on the actual practices of cannabis producers in the informal market is scant in the scientific literature (Carah et al. 2015). Nevertheless, researchers have anecdotally observed several tendencies relevant to our analysis. First, production in Humboldt typically takes place both outdoors and in greenhouses. Outdoor production relies on natural sunlight and plants are grown in groups or individually in raised beds. Greenhouse production allows for light to be diminished with shades or enhanced with artificial light. While soil quality is an important driver of cropping for most products, poor-quality agricultural soil covers nearly 90% of Humboldt County. Therefore, many growers import soil for both outdoor and greenhouse grows.[4]

Past land use analysis have shown that cannabis production is clustered at the watershed scale, with some watersheds having high levels of production and others no production at all (Butsic and Brenner 2016a). Cannabis production is most prevalent in the south and east of the county. Most production takes place in remote areas of the county, many of which are not suited for traditional agricultural production (Butsic et al. 2017). The spatial distribution of farms has been strongly influenced by past patterns of law enforcement (Leeper 1990; Butsic et al. 2017) and parcelization.

[4] While exact figures of the extent of soil importation is unknown, various local businesses supply soil in large quantities (e.g. www.humboldtnutrients.com; www.royalgoldcoco.com)

Disamenities have been reported from cannabis production. Frequently, those residing near farms express "quality of life" concerns associated with cannabis production (Mintz 2017). Many cultivation sites are located off the grid, and thus rely on generators for power. Some Humboldt County residents complain about the resulting constant humming in remote areas (Stansberry 2016b). Also many growers use artificial lights, which can lead to light pollution that may be unattractive to rural residents (Stansberry 2016a). Along with light and noise complaints, the strong odor of maturing cannabis plants draws frequent complaints from neighbors (Houston 2014; Khan 2018). Some ranchers have also reported livestock killed or injured by dogs used to protect grows (Stansberry, 2016c; *The Times Standard* 2016). And overall, there may be an unease for some potential landowners about purchasing property near cannabis cultivation, both for cultural reasons and because cannabis cultivation is still federally illegal.

Despite the existence of a legal cannabis market in California, there is strong evidence that the majority of cannabis produced in Humboldt County is sold on the black market (MacEwan et al. 2017). For example, the amount of cannabis being produced in Humboldt County during our study was likely more than sufficient to supply the entire state's legal market (Sumner, Goldstein, and Matthews 2018). Enforcement actions in Humboldt County were rare during our study period, and typically involve environmental laws and municipal ordinances such as improper road grading, rather than criminal convictions for cannabis production.

Given the long history of illicit cannabis production in our study area, many doubt that the 2018 transition to a legal recreational market will successfully formalize the supply and distribution of cannabis in California (Stansberry 2018). Benefits to producers include reduction in legal risk and potentially more lucrative marketing outlets. High barriers to entry in the legal sector may insulate producers in Humboldt County from negative price pressure in the gray or black market, which suffers from potential threats from both oversupply as well as decreases in demand due to the growth of legal substitutes in typical export locations. On the other hand, the absence of authorized interstate trade limits the size of the legal market for cannabis, which could lead to a glut if even a fraction of formerly illicit production joins the legal market. Indeed, wholesale prices on the legal market plummeted in 2017 and 2018, when many producers were authorized to supply under more loosely regulated temporary permits.[5]

Further, compliance and taxation costs are likely to be significant. In addition to a state cultivation tax $9.25 per ounce of dried flower, producers must participate in a state-wide tracking and surveillance system, subject themselves to local taxation, and submit output to stringent contaminant testing.[6] The incidence of these regulatory mandates is likely to fall most harshly on traditional outdoor producers that dominate Humboldt County. In their economic impact analysis of proposed cannabis regulations in California, MacEwan et al (2017) estimate that average total regulatory costs for typical outdoors producers will range from $207 to $248 per pound, or approximately 40 to 45 percent of average total production costs. The authors conclude that due to the nature of the regulatory costs, the type of producers typical of Humboldt County would be the "least likely to participate in the regulated market".

Methods and Data

Our primary dataset of property sales between 2009 and 2017 in Humboldt County was purchased from CoreLogic, and supplemented with data from the Humboldt County Assessors Office and ParcelQuest. We examine sales of unimproved land greater than one acre either zoned for agriculture (including pasture), forest, or timber, or designated as being used for those activities by the county assessor. We limited our dataset to these 741 sales of unimproved land because we were not able to obtain detailed information on improvements, such as the size of a structure, number of bathrooms, or number of bedrooms and therefore hedonic analysis that included developed parcels were unreliable. Further, our goal was to estimate the clearest signal possible relating cannabis and formalization to property prices, unimproved land provides the most valid comparisons across properties.

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[5] While wholesale prices paid to producers vary considerably, and exhibit high seasonality, many estimates indicate cannabis farmers in California received approximately $1,300 per pound in 2017, a decrease from 2016, with prices for outdoor cannabis down sharply in 2018—under $1,000 per pound, potentially as low as $500. As temporary permits expire, wholesale legal prices appear to be recovering somewhat in 2019. In comparison, many farmers reported nominal wholesale prices reaching $5,000 during periods of stricter enforcement at the turn of the century.

[6] Sumner, Goldstein and Matthews (2018) estimate state regulations alone to add $50 per pound to cultivation costs.

In order to identify what features of the property impacted sales price we merged the sales data with a host of spatial variables. For each parcel we calculated: the % of the property in coniferous forest, the % in hardwood forest, the % in mixed forest, % in agriculture, and % in barren land (USDA 2013); the distance to the nearest town of at least 10,000 people, the size of the parcel in acres, the distance to the ocean, latitude, and distance from the nearest paved road. In addition we calculated the % of the parcel with slope over 30%, and percent of the parcel with a southern aspect. We also identified the zoning of each parcel (Table 1).[7]

Within Humboldt County, our initial analysis is focused on 54 watersheds (out of 112) for which spatially explicit data on cannabis production exist. We use maps of cannabis production from Butsic et al (2016a) to identify the density of cannabis plants in each of these watersheds, which are representative of the county as a whole (see Butsic & Brenner 2016 for comparative statistics).[8] For each property we calculate the number of cannabis plants within a one KM radius, as well as the number of plants growing on that same property. Cannabis data are recorded in 2012 and again in 2016.

Empirical Strategy

This article has two main empirical objectives. We begin with a basic hedonic model of sales price using a large number of covariates, including a variable representing the number of cannabis plants adjacent to the property, within the 54 sampled watersheds. The number of plants within one KM of the property provides a measure of both the potential negative amenity effects of cannabis cultivation and perhaps an indicator of a particular parcel's suitability for cannabis production if, for example, positive network effects prevail.[9] We have cannabis data from two points in time, 2012 and 2016. In order to utilize sales data from years between those dates, we interpolate at the property level under the assumption of a stable linear trend between the two points. We further restrict the estimation sample to

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[7] For the Hedonic specifications, properties with multiple parcels in different zoning statuses were assigned the largest zoning status. However, cannabis permit eligibility is based on the existence of any eligible zoning status within the property.

[8] The watersheds sampled for cannabis use cover 59 percent of the transactions in our data.

[9] See Butsic et al. (2017) for a discussion of network effects and empirical evidence of cannabis farm clustering in Humboldt County.

properties transacted within a year of the cannabis sample data: 2011 through 2017. Properties transacted in 2012 or 2011 are assigned values based on the 2012 tabulation of cannabis plants, properties transacted in 2016 or 2017 are assigned valued based on the 2016 tabulation. Properties transacted from 2013-2015 are assigned values based on the interpolation.

To determine whether the opportunity to participate in the legal supply chain increases the land value of permit-eligible properties, our second identification strategy relies on the adoption of the Commercial Medical Marijuana Land Use Ordinance (CMMLUO) (Humboldt County 2016). The CMMLUO, adopted unanimously by the Humboldt County Board of Supervisors on January 26, 2016, created a permitting process for the production and distribution of cannabis in the county. The ordinance was enabled by California's passage of the Medical Marijuana Regulation and Safety Act (MMRSA), which explicitly defined a regulatory structure for medical marijuana that included a local permitting process.[10] Humboldt County was the first California county to enact land use regulations consistent with MMRSA.

In order to participate in the legal medical marijuana market, growers in Humboldt County were required to obtain a permit under CMMLUO. Beginning in February of 2016, the county began accepting permit applications, and received 2,337 separate applications by the end of the year, and an additional 600 by April 2017. That total, which includes permit applications for new cultivation sites, represents a small fraction of the estimated 15,000 cannabis farms operating at that time (Ascent Environmental 2018).

The CMMLUO defined eligibility requirements for both new and existing cultivation sites, with some differences depending on whether the parcel is located in a coastal or inland zone.[11] For new sites on parcels greater than 5 acres, the cultivation area must be (a) located on "Prime Agricultural Soil", as defined by an official county map which locates all prime soils in the county, (b) in a zoning districts

[10] The MMRSA framework later became the basis for adult-use marijuana supply regulation in California.

[11] We summarize the areas of the ordinance critical for the analysis here, which focuses on large outdoor cultivation. The ordinance details lengthy requirement for indoor and smaller grows, as well, which involve different permit types.

classified[12] as RA (Rural Residential Agriculture), AE/AG (Agricultural Exclusive/General), FP or DF (flood plain zones), FR (forestry recreation), or U (unzoned), and (c) on slope of 15% or less, and (d) have a documented water right (or non-diversionary water source).[13] We note that a water right could be easily obtained at this time in Humboldt County in two ways. First, a landowner could simply drill a well with sufficient capacity to irrigate their crop. Given the geology of Humboldt County, a well can be drilled on nearly any property. Second, at this time California started issuing water rights to cannabis farmers who were using surface water, and the vast majority of cannabis farmers who applied for these rights were granted them. Therefore, we do not consider the water right provision to be a determinant of eligibility.

We use the passage of CMMLUO as an additional means to identify the impact of cannabis cultivation on real estate prices within rural areas of the entire county. Our identification strategy rests on the fact that the ordinance affected only parcels deemed eligible for a cannabis permit, and that ineligible parcels would not have been affected by its passage. Because eligibility is based on time invariant characteristics (e.g. defined area of prime agricultural soil, slope), any change in the post-ordinance difference between eligible and ineligible parcels should be due to factors associated with the return to a cannabis permit. We implement this strategy using a straightforward difference-in-difference (DiD) estimator. Our basic approach to estimation is given by the following equation:

$$(1)\quad ln\, ln\,(p_{it}) = \beta_0 + \beta_1 Post_t + \beta_2 Elg_i + \beta_3 Post_t * Elg_i + \beta_4 X_i + \theta_t + e_i$$

Where p_{it} is the per-acre sales price of property i in year t, $Post$ is a dummy variable equal to one if the sale of the property occurred after the enactment of the ordinance, X_i is a vector of control variables that describe the geophysical and zoning characteristics of the property, and θ_t represent year fixed effects. The permit eligibility variable *Elg*, is equal to one for properties that meet the zoning, size,

[12] The zoning district restriction is stricter in coastal areas, as only AE or RA zones are allowed.

[13] Existing sites (as of Jan 1, 2016) can be grandfathered in to the permitting process on more lenient terms, including exemption from some zoning, soil and slope requirements, but may require additional site visits and cannot include expansions of existing production area. We focus on new permit eligibility, as there remains considerable uncertainty about the outcome of existing permit applications that require exemptions.

slope, and soil requirements specified in the ordinance. To construct our measure of a parcel's eligibility for a permit, *Elg*, we include in the treatment group properties that meet the zoning, size, slope, and soil requirements specified in the ordinance. Because permit requests allow applicants to designate a specified portion of their property for cultivation, properties are designated as eligible if part of the parcel satisfies the required elements. In our dataset 95% of eligible parcels had enough eligible land to grow the largest size farm permissible in Humboldt County and 100% of parcels had enough eligible land to grow at least 1500 sq ft of cannabis.

Our main specification limits the pre-treatment period to after the 2008 housing crisis and we end our analysis after 2017, using only two years of post-treatment observations. There are trade-offs between using a longer or shorter post-treatment period. In this setting, the shorter post-treatment setting captures a unique moment where Humboldt County was the only county is the state with a fully formed and functioning permit system. After 2017, neighboring counties had developed their own regulations and state-wide regulations went into effect. These changes widened the path to formalized production in much of California, but obscured the identification of clear counterfactual property sales. Therefore, January 2016 and December 2017 represents a unique period in which a property's return on legal cannabis production could be identified based on invariant parcel characteristics. In order to control for time specific effects, we also include eligibility group time trends in some estimates.

In addition to the basic DiD design, we explore the identification assumptions and change in post-ordinance land values in a variety of ways. A lag-lead analysis based on Autor (2003) is used to explore the difference in price trends between eligibility groups both before and after the ordinance implementation. Similarly, we assess average annual changes in land prices, as well as deviations from annual trends, using the methodology in Finkelstein (2007) and Lawley (2018). Finally, as in Gavrilova, Kamado, and Zoutman (2017) we implement an in-space placebo analysis by randomly assigning eligibility status and comparing our estimates to the simulated results.

Results

We first estimate a basic hedonic model as a means of describing the determinants of sale price in our sample, as well as the baseline relationship between land prices and cannabis production. We estimate models with and without watershed fixed effects in Table 2.

The number of plants within one kilometer of the transacted property has a generally positive relationship with the log of the sales price per acre over all estimations. The estimates suggest that an increase of 100 cannabis plants within one KM of a property is associated with a 1 percent increase in that property's sales price. The median transacted property in the sample has nearly 400 cannabis plants within one KM.

While neighboring cannabis farms are positively associated with land values, the coefficient on the number of cannabis plants on transacted properties is negative and insignificant. Because of the sample selection inherent in transacted property sales data, the null relationship could potentially reflect differential patterns in transactions on cannabis farms themselves. However, the volume of transactions do not appear to support that explanation. Between 10 and 15 percent of the transacted properties had cannabis farms at the time of the sale, which is close to the fraction of parcels in the sample that had confirmed cannabis farms in 2012 or 2016 (8 and 12 percent, respectively).[14] Alternatively, the use of interpolation may be more pivotal for own-property data, which are inherently less smooth than aggregated neighboring cannabis density.[15]

Several other relationships are worth noting. In all specifications, size has a negative, quadratic relationship with per acre sales prices. Properties classified as agricultural have a strong positive relationship with sales price. The same is true for properties near the ocean, reflecting a strong premium for coastal properties. Similarly, properties closer to cities have higher sale prices, which corresponds to national findings in Borchers, Ifft, and Kuethe (2014). The imprecise estimate of this variable may owe

[14] The range of 10 to 15 percent reflects the use of either 2012 or 2016 cannabis data to determine if cannabis existed on properties transacted between 2013 and 2015.

[15] Alternative assignments of own-property cannabis between 2013 and 2015 reduce the precision of the estimate, but the direction and magnitude of the coefficient remain similar.

to the collinearity with coastal distance, as population centers in Humboldt County are primarily coastal. Timberland also appears to be significantly less valuable than other types of properties, as properties with a history of timber harvest are more than 50 percent less valuable on a per acre basis, on average.

Finally, as expected, including watershed fixed effects reduces the power of property level attributes to explain sales prices, as these attributes are often naturally correlated within clusters. However, cannabis density, remains a positive and significant indicator of land prices across specifications, suggesting that the relationship is not spuriously generated by higher production in coincidentally higher value watersheds.

The pattern of results is consistent with the idea that cannabis and land values are positively linked in Humboldt County. We do not observe any evidence that disamenities from neighboring cannabis farms have depressed land values, though we lack a clear counterfactual to provide more insight into the causal structure of the relationship. While it is highly unlikely that the positive correlation is a result of reverse causality—e.g. being surrounded by more valuable land induces cannabis production—we cannot distinguish the extent to which the relationship owes to higher returns from potential cannabis production (i.e. agricultural use value) or from secondary effects of increased local income. In the following section, we therefore explicitly explore the causal relationship between potential returns to legal cannabis production and land values.

Impact of formalization on land prices

In this section, we exploit the enactment of a land use ordinance that created a permitting process for cannabis producers in order to estimate the land price impacts of legalized cannabis production. The eligibility requirements for obtaining a new permit favor land suitable for traditional agricultural uses: flat parcels with prime agricultural soil. Butsic et al. (2017) note that prior to the passage of the ordinance, the spatial distribution of cannabis production in Humboldt County did not favor such parcels, with production often occurring on slopes in remote forests using imported soils. As seen in Table 1, eligible parcels tend to be more valuable, flatter, less forested, closer to the coast, more likely to be classified as agricultural.

In Figure 2, we overlay the parcel eligibility criteria with data on the number of cannabis plants from a random sample of watersheds. Eligible parcels are often found in coastal areas with relatively light cannabis production intensity, but also cross over into more intensely cultivated watersheds inland. The distributed placement of these parcels suggests that, outside of agricultural suitability, both eligible and ineligible parcels would be subject to similar pre-ordinance land market factors.

We use a Lowess smoother to depict the trends in the log of per acre prices among eligible and ineligible properties before and after the introduction of the ordinance. In our estimates, we vary the pretreatment period to examine the sensitivity of our results to the possible influence of differential responses to the 2008 financial crisis that greatly impacted the real estate market. The nonparametric estimate of land values in the sample from Figure 2 suggests that in the time period under study, trends by eligibility group appear similar prior to the introduction of the ordinance. After the introduction of the ordinance, however, the prices of eligible properties appear to rise, while ineligible property prices remain relatively stable.

Regression results from the DiD specification indicate that after the enactment of the ordinance, the sale prices of properties eligible for a cannabis production permit increased relative to those not eligible (Table 5). The magnitude of the effect is positive, large and statistically significant across specifications that exclude all control variables (column 1), includes controls (column 2), and include an additional linear trendy by eligibility (column 3).

In the standard specification from column 2, the coefficient estimate of .64 transformed according to Kennedy (1981) corresponds to an 84 percent relative increase in the sale price of eligible land. Including a group specific linear time trend increases that estimate to approximately 190 percent. These estimates support anecdotal observations of dramatic land price increases attributable to cannabis in Humboldt County. These main estimates are robust to extending and contracting the pretreatment period, as shown in Appendix Table A.1.

Robustness Checks and Falsification Tests

In this section, we conduct a variety of alternative estimates to assess the reliability of the results in Table 3. The first analysis flexibly estimates the impact of eligibility by including a separate coefficient on eligibility in two-year increments. Our preferred estimate uses two-year groups, instead of a separate estimate for each year, because the paucity of transactions in the years following the financial crisis lead to very imprecise annual estimates, as seen in Appendix Figure A.1. As in Autor (2003), the coefficients from the 'lag-lead' analysis are graphed in figure 4, with the last full year (2015) before the enactment of the land use ordinance serving as the reference year. The figure demonstrates two patterns. Before the ordinance, the difference estimates were never statistically significant, and were small as the ordinance date approached. That lends support to the assumption of conditional parallel trends between eligible and non-eligible properties prior to the ordinance. However, after the ordinance went into effect, land values of eligible properties increased sharply, with a much narrower confidence interval, suggesting a distinct relative increase after the passage of the ordinance. As seen in Appendix Figure 1, prices of eligible properties remained relatively high in 2017.

An alternative to the point-by-point estimation illustrated in figure 4 explicitly estimates a separate linear trend for both eligible and non-eligible parcels over the sample period, and allows for a trend difference after the imposition of the ordinance. Such a "deviation from trends" analysis is used by Finkelstein (2007) to estimate the impact of the introduction of Medicare on medical spending, and by Lawley (2018) to estimate the land price effect of alleviating land use restrictions in Canada. We implement the model by estimating the following equation:

$$ln\, ln\, (p_{it}) = \alpha Elg_i + \beta_1 t_t * Elg_i + \beta_2 (t_t - 2015) * Elg_i + \beta_3 X_i + \theta_t + e_{it} \qquad (2)$$

Here, the t_t represent linear time trends, and $(t_t - 2015) = 0$ for all $t < 2016$. The coefficient of interest is β_2, which is the estimated post-ordinance deviation from trend for eligible properties. As in the baseline model, the specification here restricts, *ex-ante*, the change in trends to occur in 2016. However, as the lag-lead analysis indicates, the less flexible approach is reasonable given the apparent rise in property values coinciding with the implementation of the ordinance. In addition, as noted by both

Lawley (2018) and Finkelstein (2007), unlike the more flexible year by year approach, the estimates here fully use the entire sample period and are not dependent on similarities in magnitudes between adjacent years.

The estimate from the deviation-from-trends analysis likewise supports a large and positive impact of the ordinance. Using the primary sample, the transformed coefficient indicates a 124 percent increase in the relative sale price of eligible parcels following the ordinance, with the estimate significant at the 1 percent level. However, if the pre-treatment period is set to 2012, the magnitude of the estimate is cut by half.

In the final check on our results, similar to Gavrilova, Kamada, and Zoutman (2017), we implement an 'in-space' placebo test using non-eligible properties. To determine if the non-eligible properties in fact represent a valid counterfactual for eligible properties, or if the estimation procedure is spuriously generating the positive impact of the ordinance on land prices, we randomly assign treatment status and re-estimate the baseline model. Specifically, properties transacted in a given year are randomly assigned eligibility status without replacement under the condition that the number of pseudo-eligible properties in a given year match the true number of eligible properties.

Because there was no relative change between non-eligible parcels in 2016, the true value of the pseudo-DiD parameter should be zero. If the placebo regressions generate estimates close to those in Table 3, the regression adjustment itself, instead of the policy change, cannot be excluded as causing our positive estimated impact.

The procedure is simulated 10,000 times, and the resulting parameter estimates plotted in Figure 5. The estimates are centered around zero, as expected. The dashed line represents the 95^{th} percentile of the placebo coefficients, and the solid line the DiD estimate from column 2 of Table 3. The estimate from the actual data is far to the right of the 95 percent line, meaning that the preferred estimate and inference are unlikely to be artifacts of the estimation strategy.

Similarly, an alternative explanation that might account for our results is an increase in demand for cannabis eligible parcels unrelated to cannabis production. Given the zoning and soil requirements, eligible parcels are also suitable for traditional agriculture, most commonly pasture or animal husbandry based. If demand for such parcels spiked at the same time as the enactment of the CMMULO, the subsequent increase in land values may be attributed to cannabis eligibility. However, we do not see any evidence that this is the case. The USDA annual land value report estimates that per-acre pasture prices in California were unchanged between 2015 and 2017 (USDA 2017). Further, neither the 2016 nor 2017 reports of the California Chapter of American Society of Farm Managers and Rural Appraisers note sharp changes in land value trends in the North Coast for pasture or cropland (Forcey et al. 2017, 2018). Thus, while we cannot completely rule out that our results stem from a differential trend in demand for agricultural land, the available secondary evidence does not support that explanation.

Finally, we conduct a placebo test using land values in neighboring Mendocino county. Like Humboldt, Mendocino has a long history of illicit cannabis production.[16] The coastal counties are agroecologically similar, with considerable forest cover and little traditional row crop agriculture. Mendocino did not pass an ordinance establishing a cannabis cultivation permitting system until April 2017, over a year after Humboldt did so, and continued revising application deadlines and permit eligibility criteria in the months after passage. Importantly, unlike in Humboldt, eligibility for a permit was not conditioned on invariant parcel characteristics like soil and slope, and focused instead on zoning and requiring a five acre minimum property size. Therefore, finding that Mendocino county parcels satisfying the requirements of Humboldt's permitting ordinance experienced a relative price increase after enactment of the Humboldt county ordinance would suggest the previously estimated large land price effects in Humboldt were not solely due to legal cannabis cultivation opportunities and instead a result of other trends affecting the market for undeveloped land in California's North Coast.

As in Humboldt, our sample of transacted properties in Mendocino consists of properties greater than one acre either zoned for agriculture (including pasture), forest, or timber, or designated as being used for those activities by the county assessor.

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[16] Along with Trinity, Humboldt and Mendocino counties comprise California's "Emerald Triangle" region, where outdoor and mixed light cannabis production have thrived for decades.

We construct our placebo eligibility variable for Mendocino by assigning an “eligibility” dummy to the 343 properties transacted between 2009 and June 2017 based on Humboldt county’s soil, slope and zoning criteria (a smaller percentage of Mendocino properties—10%--meet the criteria than in Humboldt, where the figure is 16%).

In Mendocino, very few properties–six–were transacted after the 2016 Humboldt ordinance. The lack of a post-ordinance change in transactions is suggestive that there was no differential change in demand unrelated to cannabis formalization for land meeting permit eligibility in Northern California. However, the small number of post-ordinance transactions necessarily limits the power of the placebo tests.

Nevertheless, we replicate as much as possible the standard DiD specification from column 2 of Table 3 using Mendocino data. To account for possible impacts of Mendocino’s own ordinance, we include a separate dummy variable for properties greater than five acres. Because we include the new five acre dummy, and one control variable (the Southern aspect of the property), is not available in the Mendocino data, we also reestimate equation (1) for Humboldt.

The DiD estimate in Mendocino is small, negative and highly insignificant (p=.925) (Table 5, column(1)). For Humboldt, the slight change in time period and the change in controls has no substantive impact on the estimates, which are nearly identical to the original (column (2)). Grouping the counties and estimating the triple difference specification suggest that that the relative post ordinance increase in eligible land prices in Humboldt was larger than the relative increase in Mendocino. However, the estimate is not statistically significant, likely due to the imprecision from adding the Mendocino observations.

While these results do not suggest the land price impacts observed in Humboldt are the result of generic factors influencing the market for agriculturally suitable land, they should be taken with caution. As noted, only six eligible parcels were transacted after the introduction of the ordinance in early 2016 and prior to the end of the sample period (June 2017). While the point estimates in Mendocino are close to zero, the large estimated standard errors limits our ability to conclude that these placebo results are precisely estimated null effects.

Discussion

Rural land use and economies continue to change. Here, we investigate the impact of an expanding and economically important land use: cannabis production. Using Humboldt County as our case study, we estimate the relationship between cannabis production and property prices. Our findings suggest that the increases in productive capacity of land brought about by cannabis production outweigh negative disamenity impacts of cannabis production. Likewise, we find that buyers are willing to pay a sizable premium for land from which cannabis can enter the legal supply chain, even though the gray and black market continues to thrive in California.

Our paper makes several contributions to the existing literature. First, we offer credible evidence on the role of cannabis in driving real estate price appreciation in the 'emerald triangle'. Properties within the vicinity of cannabis appear to sell at higher prices, and eligibility for legal production sharply increased land values. Second, we bring strong evidence to bear on a critical question facing policy makers as they attempt to formalize the cannabis supply chain: will producers view the legal market as a viable alternative to the black market given the potential tax and regulatory hurdles associated with the legal supply chain? The evidence from Humboldt County land purchases suggests that the legal market was is an attractive option, at least during the time period of our study (2016-2018). For permit eligibility to cause the spike in land prices we observe, buyers would need to anticipate relatively higher legal returns to cannabis. This suggests that there was a class of investors who placed faith in the legal market.

While our results use exogenous variation in returns to licit cannabis production to identify the impact of cannabis policy on land values, they suffer from the usual weakness of studies that rely on transacted sales data. The lack of repeated parcel sales, a common characteristic of rural land studies, means that we cannot completely exclude the possibility that the composition of unobserved characteristics of the transacted property sample changed in a systematic manner strongly correlated with permit eligibility after the enactment of the land ordinance. However, we believe that to be unlikely, because limiting the sample to only undeveloped land reduces the risk of this particular form of selection bias. Unfortunately, doing so constricts the sample, which results in varying magnitudes of the estimated impact.

There are likely several mechanisms that influenced these land price changes. One ‘pull’ factor was is the anticipation of a more lucrative legal market. Marketing opportunities that allow producers to distinguish their output as a premium product could lead to higher sale prices that outweigh the anticipated regulatory costs. Indeed, Humboldt County, with its long reputation for cannabis production, was at the forefront of efforts to promote appellation in cannabis packaging.

In contrast, ‘push’ factors include expected increase in enforcement associated with illicit production. As track and trace becomes standard throughout the state, and the ‘gray market’ conditions that prevailed in the medicinal use era recedes, illicit producers should be less able to blend in with legal producers. Further, regulators signaled that enforcement efforts will be stringent once the licensing process matures. Indeed, Humboldt County began sending abatement notices—accompanied by the threat of heavy fines ($10,000 a day)—to those suspected of cultivating without a license in the latter half of 2018. . .

As more communities codify land use regulations regarding cannabis growing, similar increases in other geographic locations may be expected (Fuller 2017). More generally, the future relationship between agricultural land values and sanctioned cannabis will depend on the nature of regulations adopted by states and municipalities that choose to legalize the product’s production. A crucial element of those regulations will be farm size restrictions. Caulkins (2010) estimates that, at scale, the land area required to satisfy domestic consumption in the US totals less than 5000 acres, or a hundredth of one percent of US cropland. However, regulations in many states currently cap the size of production from a single farm, spreading both the geographic distribution of production as well as the land price effect. Producers have pressured for changes to these laws as wholesale cannabis prices have fallen in states that have legalized production. The state of Washington, which limited the maximum single farm size to 30,000 sq feet, has recently modified their regulations to permit a single operator to hold up to three licenses, and California's most recent set of regulations likewise allow multiple license holders.[17] While the size of an individual farm in California is still nominally capped at one acre, several localities have allowed these one acre parcels to be contiguously operated as a single large farm. Thus, the larger real estate impacts of cannabis will be highly dependent on how localities regulate consolidation in production.

Property price increases, such as the ones we estimate after the 2016 ordinance, have the potential to be disruptive in many ways. Of particular interest to agricultural economists may be the competition for land between cannabis growers and other agricultural practices. The land use ordinance explicitly encourages cannabis cultivation in prime agricultural areas, increasing competitions for these scarce properties. That may potentially price out other more traditional land uses such as ranching or row crop agriculture. For young farmers looking to start a non-cannabis operation, such prices may make investments in land prohibitively expensive.

Finally, the strong performance of farmland asset classes has sparked recent debate concerning the sustainability of current land values (Sherrick 2018). Those concerns apply to Humboldt County, which has seen continued land value appreciation. The large increase in land prices caused by the land use ordinance similarly raises questions about the future performance of land values associated with cannabis production in Northern California. Recent declines in the wholesale price of cannabis suggest that output net revenues may not be sufficient to justify current asset price levels. With an ever-shifting regulatory framework and continued changes in the marketing landscape, the situation for rural cannabis producers, and for land markets, in the North Coast is likely to remain dynamic for some time.

How should the large premium for legal cannabis production in Humboldt county at the inception of formalization be viewed in light of contemporary concerns about the viability of California's legal market? For example, Goldstein and Sumner (2023) argue that California's legal market has failed to meet growth and profitability expectations and that both illegal cultivation and retail transactions

[17] A group of small cannabis producers sued to block California from allowing consolidated operations (Blood 2018), but have withdrawn their suit.

remain widespread. From that perspective, the optimism that fueled the land price rise we observe in Humboldt would appear to have been misplaced.

A counterargument would be that the legal market has in fact continued to grow, with taxable sales tripling between the first quarter of 2018 and 2023 (California Department of Tax and Fee Administration 2023). The high barriers to entry and regulatory burdens cited by Goldstein and Sumner (2023) as a drag on legal producers can be seen as creating competitive barriers that justified the land-price premium required to be an early entrant in Humboldt's system. Regardless of whether such premiums can be justified *ex-post*, it is clear that the future path of cannabis production in California remains uncertain. Starting in 2021, legal cannabis sales have declined in 6 of the last 8 quarters, and remain down from their early 2021 peak of $1.6 billion.

In hindsight, did the spike in land prices observed in Humboldt at the onset of formalization provide insight into the subsequent direction of California's legal market? Our estimates implied strong demand for producers to enter the legal market, and indeed, that prediction is consistent with permitting behavior in Humboldt county. The initial formalization period saw over 2,000 producers apply for permits in Humboldt, but demand for permits appears to have abated.

The estimates here also provide some insight into the importance of policy choices in the design of legal cannabis markets. Tax, regulatory and compliance costs for legal producers are high. Small producers, in particular, find regulations complex and difficult to navigate, and have been much more reluctant to enter the legal market (Polson et al 2023; Schwab et al 2019). The land price estimates imply farmers expected substantial premiums to operate in the legal market, which, according to Goldstein and Sumner (2023), have not materialized. The tension between the high initial demand for entry, current stagnation in the legal market, and the continued robustness of the illegal market suggest that the level of regulatory barriers to compliance is a key determinant of legal market viability. Our analysis suggests that the actual costs and regulatory burdens in the regulated market likely exceeded expectations.

Indeed, the future path of land prices will likely depend on the extent to which returns to legal and illegal production diverge, and the evolution of the cannabis supply chain. If formalization efforts lead to increased enforcement, Humboldt County's status as a center of cannabis production will depend on whether the region offers any comparative advantage, either from institutional factors derived from the area's production history (e.g. networks, knowledge), or product attributes (e.g. 'terroir', branding). As other areas of California have lower potential production costs, even if output prices stabilize, property prices in Humboldt may decline in the future if growers locate to areas that provide a higher return.

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Table 1: Data Summary

Variable	Definition	Data Source	Eligible Properties [N=116]	Ineligible Properties [N=625]	Difference
Price/acres	Sale Price divided by parcel size	*1*	31214 [3201.64]	13569 [2025.52]	17644***
Parcel size	Size of parcel in acres	*2*	28.31 [4.54]	120.20 [23.09]	-91.89***
NP1km	Number of cannabis plants within one KM of the property	*3*	1643 [459]	2683 [453]	-1040*
numplants	Number of cannabis plants on the property	*3*	819 [686]	5324 [1064]	-4505***
Elg	Eligible for new cannabis cultivation permit (see text)	*3*	1	0	--
Slope 30	Percent of parcel with slope>30%	*3*	0.04 [0.01]	0.22 [0.02]	-0.18***
Percent mixed forest	Percent of parcel in mixed forest	*4*	0.18 [0.04]	0.39 [0.03]	-0.21***
Percent hardwood	Percent of parcel in hardwood forest	*4*	0.10 [0.03]	0.20 [0.02]	-0.10***
Percent shurb	Percent of parcel in shrub land	*4*	0.01 [0.01]	0.01 [0.00]	0.00
Percent coniferous	Percent of parcel in coniferous forest	*4*	0.14 [0.03]	0.23 [0.02]	-0.09**
Percent barren	Percent of parcel barren	*4*	0.03 [0.01]	0.02 [0.01]	0.01
Agland	Percent of parcel with agriculture	*4*	0.68 [0.06]	0.07 [0.02]	0.61***
lnroaddis	Distance of parcel to road in km	*5*	0.15 [0.03]	0.24 [0.03]	-0.09*
Distance to stream	Distance to nearest stream/water in KMs	*6*	0.55 [0.13]	0.35 [0.05]	0.20
THP	Equal to 1 if a Timber Harvest Plan was ever on parcel from 1997-2012	*7*	0.07 [0.03]	0.24 [0.03]	-0.17***
Distance to ocean	Distance to ocean in hundreds of KMs	*6*	0.15 [0.03]	0.23 [0.02]	-0.08***
Northness	Y coordinate in meters	*8*	142.17 [8.37]	136.93 [6.67]	5.24
Distance to city	Distance to city in in hundreds of KMs	*2*	0.86 [0.16]	1.31 [0.08]	-0.45***
Multsale	Multiple parcels in one property sale	*1*	0.12 [0.03]	0.14 [0.02]	-0.02

Means of estimation sample (properties transacted between 2009 and 2017), with standard deviation in brackets. Sale price in 2016 USD. Asteriks based on p-values calculated from T-tests of mean differences, with standard errors clustered at watershed level. * p<0.1 ** p<0.05; *** p<0.01 For *numplants* and *NP1km*, N=72 and 365 for each column. Data Source: 1=CoreLogic; 2= Humboldt County parcel layers (http://www.humboldtgov.org/201/Maps-GIS-Data); 3=Calculated from Butsic & Brenner (2016); 4=CalVeg (http://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192); 5= Derived from road layer from Humboldt GIS (http://www.humboldtgov.org/201/Maps-GIS-Data); 6= California Department of Fish and Wildlife (https://www.wildlife.ca.gov/Data/GIS/Clearinghouse); 7= CALFIRE http://calfire.ca.gov/resource_mgt/resource_mgt_forestpractice_gis; 8= Calculated in ArcGIS

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Table 2: Determinants of Land Sales Prices in Humboldt County between 2011 and 2017

	(1)	(2)	(3)
Plants w/in 1km of property (hundreds of plants)	0.006	0.007	0.009
	(0.002)**	(0.002)**	(0.004)*
Number of plants on property (hundreds of plants)	-0.001	-0.001	-0.002
	(0.001)	(0.001)	(0.002)
Parcel Size (acres)	-0.002	-0.002	-0.001
	(0.001)*	(0.001)*	(0.001)
Acres^2	0.000	0.000	0.000
	(0.000)*	(0.000)*	(0.000)
Zoned for agriculture	-0.020	-0.223	-0.241
	(0.193)	(0.274)	(0.266)
Slope30	1.836	0.993	1.926
	(0.645)**	(0.429)*	(0.528)**
Percent Ag	-0.224	-0.136	0.039
	(0.220)	(0.222)	(0.282)
Percent mixed forest	-1.550	-1.477	-3.077
	(0.614)*	(0.622)*	(0.517)**
Percent hardwood	-0.593	-0.197	-0.166
	(0.335)	(0.402)	(0.433)
Percent shrub	0.489	0.641	0.666
	(0.351)	(0.355)	(0.418)
Percent coniferous	0.119	0.461	0.382
	(0.308)	(0.273)	(0.395)
Percent barren	0.253	0.452	0.594
	(0.330)	(0.258)	(0.499)
Distance to road	1.598	1.263	1.291
	(0.783)*	(0.559)*	(1.054)
Distance to Stream (KMs)	-0.108	0.241	0.291
	(0.399)	(0.373)	(0.476)
Aspect	1.709	1.380	1.527
	(1.010)	(1.079)	(1.212)
THP	-0.281	-0.087	-0.385
	(0.144)	(0.173)	(0.184)*
Distance to ocean (Hundreds of KMs)	0.446	0.406	0.422
	(0.201)*	(0.254)	(0.281)
Northness	-0.311	-0.022	-0.351
	(0.291)	(0.301)	(0.371)
Distance to city (Hundreds of KMs)	-0.633	-0.221	-0.455
	(0.228)**	(0.269)	(0.416)
Multsale	-2.221	-6.112	-5.157
	(0.732)**	(1.285)**	(1.435)**
R^2	0.40	0.58	0.67
N	290	279	215
Watershed FE	No	Yes	Yes + WS Trends

Dependent variable is the log of per acre sale price in 2016 USD and estimation excludes one percent tails of dependent variable distribution. Estimation sample is sales between 2011 and 2017. All estimates control for year of sale. Variable definitions in table 1. Robust standard errors in parentheses. * p<0.1 ** p<0.05; *** p<0.01.

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Table 3: Impact Estimates of the Land Use Ordinance on Land Prices (DiD)

	(1)	(2)	(3)
DiD [ElgXPost]	0.578 (0.267)**	0.641 (0.253)**	1.142 (0.378)***
N	*741*	*741*	*741*
Controls	None	All	All
Group Time Trend	None	None	Linear
Years	2009-2017	2009-2017	2009-2017

Estimated coefficient of interaction term (β_3) from equation (1), with standard errors clustered at the watershed level. Dependent variable is log of per acre sale price in 2016 USD and estimation excludes one percent tails of dependent variable distribution. Estimation sample is sales between 2009 and 2017. Controls include all variables in Table 2 excluding the cannabis measures (first two rows), year of sale, as well as separate dummies for *post* and *elg*. Estimates in column (3) also control for linear time trend by eligibility group * p<0.1 ** p<0.05; *** p<0.01.

Table 4: Impact Estimates of the Land Use Ordinance on Land Prices (Deviation from Trends)

	(1)	(2)	(3)
Elg*t-2015	0.857 (0.216)***	0.849 (0.226)***	0.571 (0.320)*
N	*787*	*742*	*610*
Years	2008-2017	2009-2017	2012-2017

Estimated coefficient of interaction term (β_2) from equation (2), with standard errors clustered at the watershed level. Dependent variable is log of per acre sale price in 2016 USD and estimation excludes one percent tails of dependent variable distribution. Estimation sample is sales between 2009 and 2017. Controls include all variables in Table 2 excluding the cannabis measures (first two rows), year of sale, as well as separate dummies for *post* and *elg*. * p<0.1 ** p<0.05; *** p<0.01.

Table 5: Impact Estimates of the Land Use Ordinance on Land Prices in Mendocino and Humboldt Counties

	(1) Humboldt	(2) Mendocino	(3) DDD
ElgXPost	0.638 (0.255)*	-0.105 (0.647)	-0.197 (0.669)
ElgXPostXHumboldt			0.764 (0.720)
N	722	245	967
Counties in Sample	Humboldt	Mendocino	Mendocino & Humboldt
Years	2009-2017	2009-2017	2009-2017

Row 1 is the Estimated coefficient of interaction term (β_3) from equation (1), with standard errors clustered at the watershed level. Row 2 is the triple difference interaction. Dependent variable is log of per acre sale price in 2016 USD and estimation excludes one percent tails of dependent variable distribution. Estimation sample is sales between 2009 and 2017. Controls include all variables in Table 2 excluding the cannabis measures (first two rows), year of sale, Southern exposure, as well as separate dummies for *post* and *elg* and properties greater than five acres * p<0.1 ** p<0.05; *** p<0.01.

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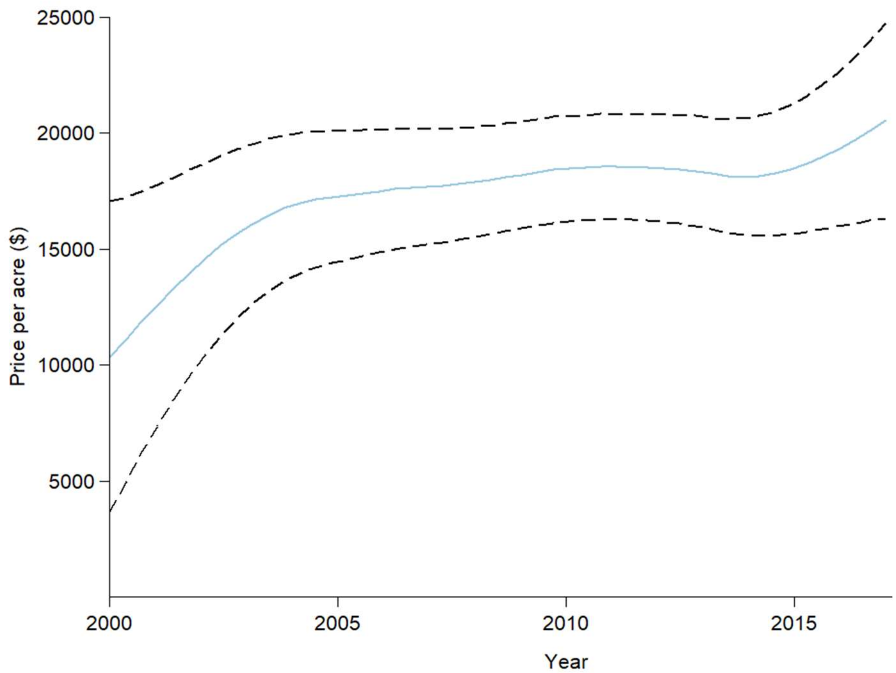
Figure 1: Per-acre sales price of undeveloped land in Humboldt County (2000-2017)



Sales price per-acre of unimproved land by year in Humboldt County, excluding 1% tails. Local polynomial regression using Epanechnikov kernel (solid line) of degree 1, using rule-of-thumb bandwidth from command lpoly in Stata. Dashed lines represent 95 percent confidence bands.

Figure 2: Location of eligible parcels and cannabis production in Humboldt County (2012)

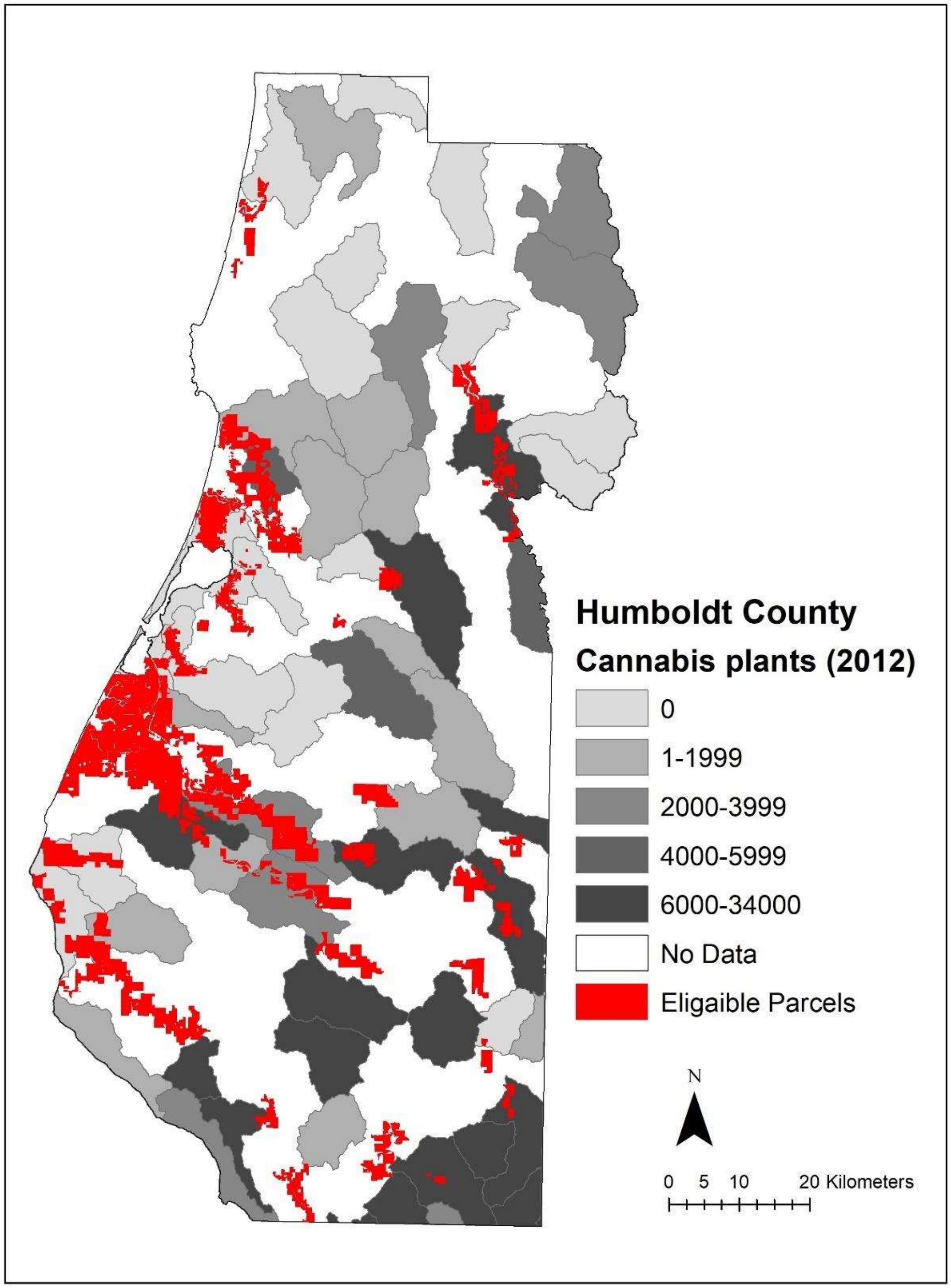
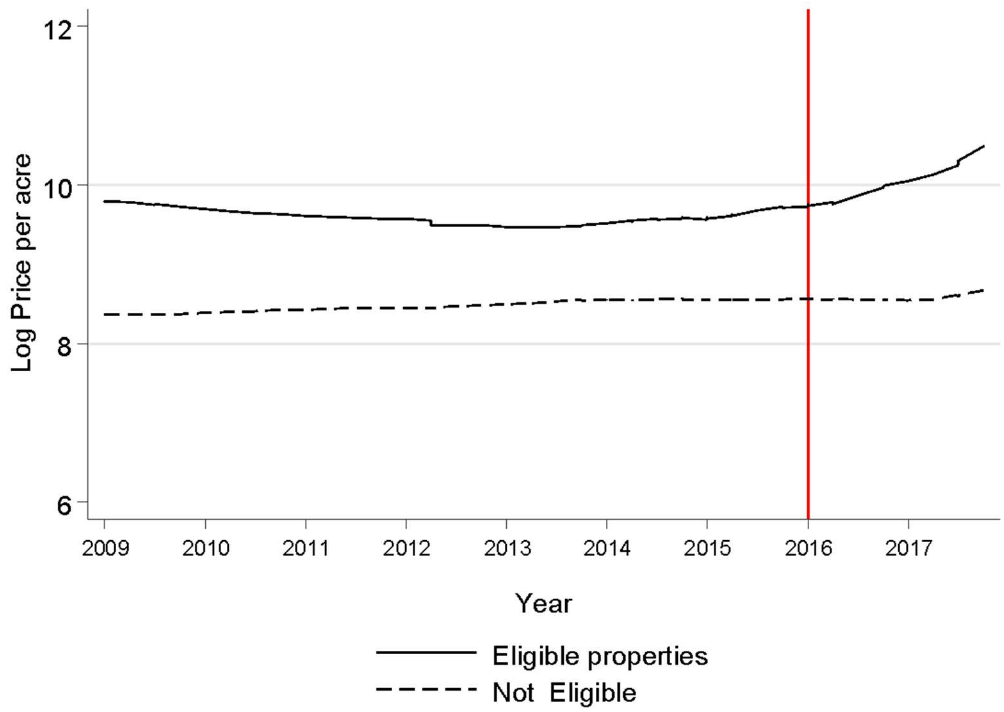
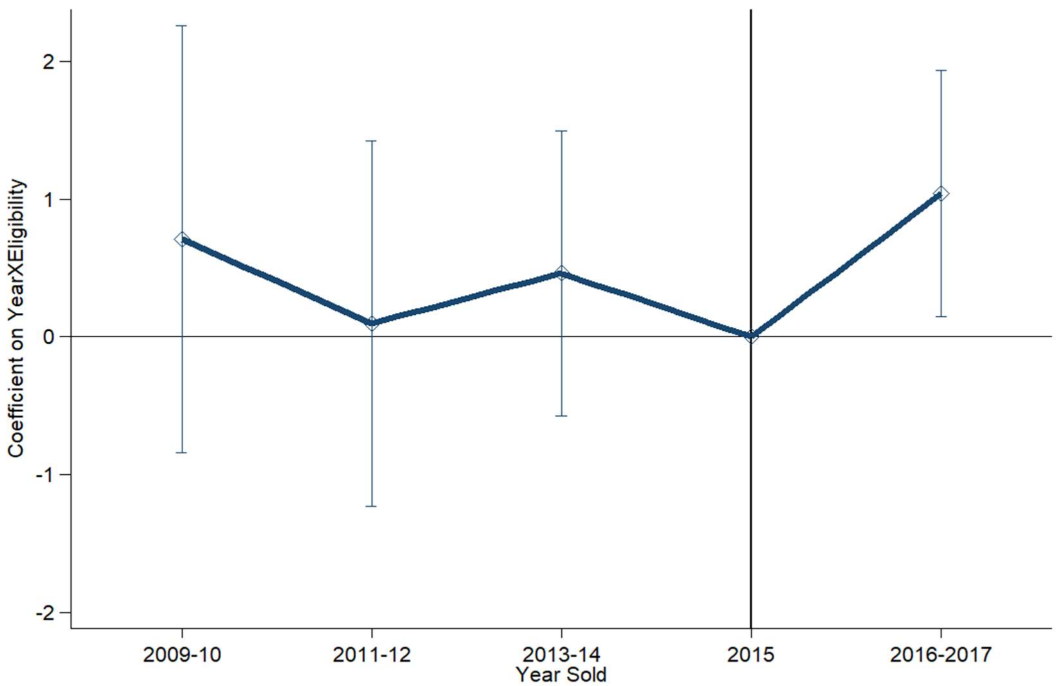


Figure 3: Trends in sale price per acre by permit eligibility



Sales price per acre of unimproved land by year and eligibility status in Humboldt County, excluding 1% tails. Estimate derived from locally weighted regression smoother using Stata's lowess command and bandwidth of .8 See text for eligibility definitions.

Figure 4: Estimated Impact of Ordinance on Log Sales Price per Acre in Two Year Bands Before and After Implementation at the Beginning of 2016



Impact estimates of ordinance implementation derived from adjusting equation (1) to include a full set of time by eligibility interactions, where years are measured in 2-year bands before and after 2015. All impacts are relative to 2015, the last untreated year. Bars represent 95 percent confidence bands from standard errors clustered at the watershed level.

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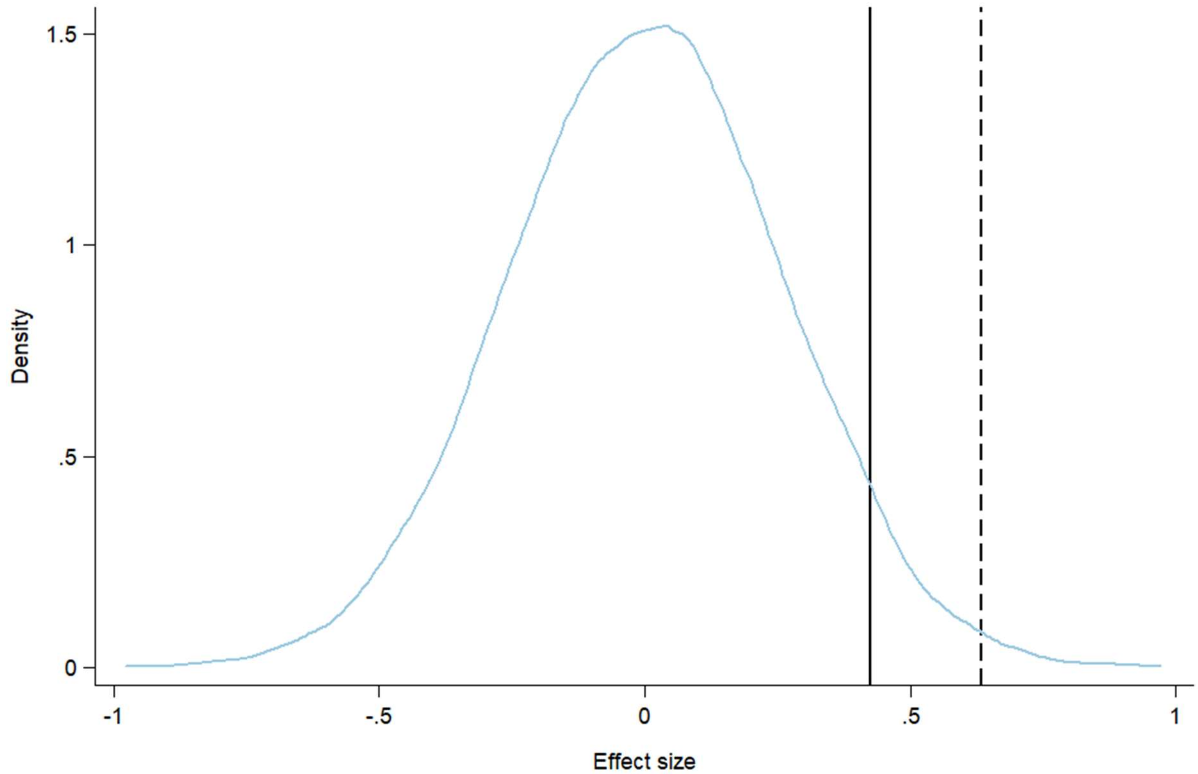
Figure 5: Placebo Graph without linear trend



Graph of the distribution of (β_3) from equation (1) derived from 10,000 replications of randomly assigning permit eligibility among the sample. The solid line denotes the 95th percentile of the distribution, and the dashed line the estimate from column (2) of Table 3.

Appendix

Appendix Table A1: DD Estimates of Impact of Ordinance on Land Prices

	(1)	(2)	(3)
DiD [ElgXPost]	0.498	0.594	0.926
	(0.254)*	(0.253)**	(0.281)***
N	*974*	*786*	*609*
Controls	All	All	All
Group Time Trend	None	None	None
Years	2005-2017	2008-2017	2012-2017

Estimated coefficient of interaction term (β_3) from equation (1), with standard errors clustered at the watershed level. Dependent variable is log of per acre sale price in 2016 USD and estimation excludes one percent tails of dependent variable distribution. Controls include all variables in Table 2 excluding the cannabis measures (first two rows), year of sale, as well as separate dummies for *post* and *elg*. * p<0.1 ** p<0.05; *** p<0.01.

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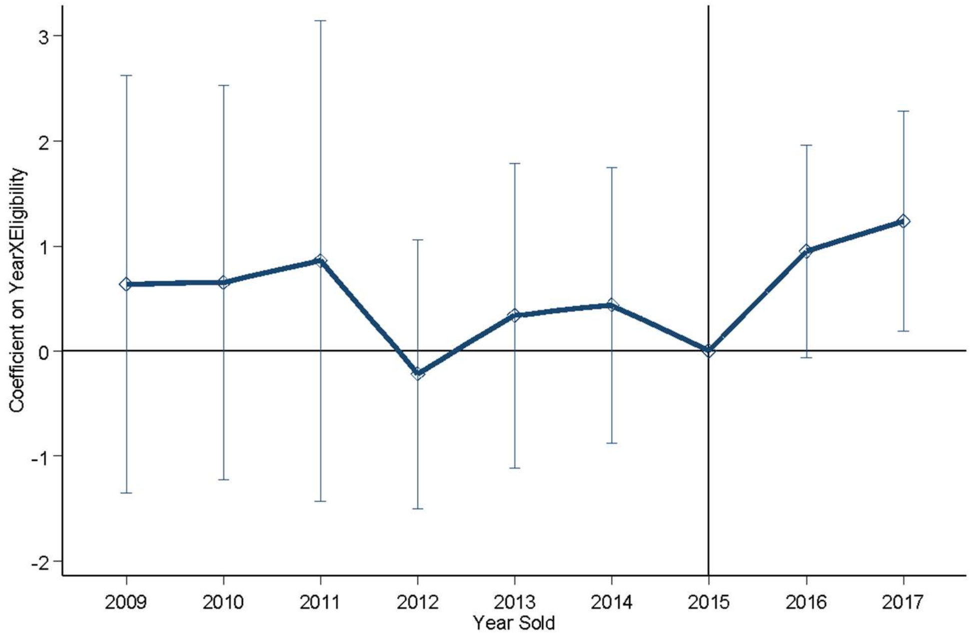
Appendix Figure A.1: Estimated Impact of Ordinance on Log Sales Price per Acre by Year



Impact estimates of ordinance implementation derived from adjusting equation (1) to include a full set of time by eligibility interactions. All impacts are relative to 2015, the last untreated year. Bars represent 95 percent confidence bands from standard errors clustered at the watershed level.