

Final Project

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I. Introduction

In this project I aim to examine the issue of gentrification in the city of Denver as caused by redlining in the past as well as the legalization of marijuana in the state of Colorado. The concentrated poverty in Denver due to redlining is the first thing I wish to demonstrate in my analysis. Historical redlining and its effects remain a problem in many cities across all states, and Denver is no exception. The effects of redlining are present in the racial and socioeconomic make up of many neighborhoods, and these clusters can be attributed to historical redlining (Kowalski). Because these areas were branded as less desirable in the past, their condition remains underdeveloped and invested-in today, as these areas remain impoverished and largely consist of minority populations, such as black people, Hispanic people, and other people of color (Kowalski). Understanding the continued effect of redlining is vital to move towards eliminating this problem, along with racial residential segregation and pockets of concentrated disadvantage across the city.

Gentrification is equally important to understand and analyze because it is changing the landscape, diversity, and overall composition of Denver and surrounding areas very rapidly. The term gentrification is used to describe the process by which more investment occurs in an area that was previously disadvantaged or resources were not allocated to, causing wealthier, and often times whiter, residents to move in and displace previous residents. This investment can take the form of renovating or constricting new properties, building high end shopping areas, opening luxury restaurants, and other changes that could cause housing costs to spike in a given area and bring in wealthier renters and homeowners (Green).

One major factor that contributed to and still contributes to gentrification in Denver is the legalization of marijuana. In 2012, the state of Colorado voted to legalize the use of marijuana for residents over 21. This change in legislation has created an influx of young residents into Denver's previously under-privileged and more disadvantaged areas where dispensaries and breweries are opening or remodeling. Specifically, these areas are former hot-spots for drug arrests and related activities. Areas that previously held this reputation were some of the first to open marijuana dispensaries, causing a new demographic to flood into these areas. The migration of younger, wealthier residents has led to the opening of more luxury restaurants, bars, and retail stores, leading to higher rent prices that are forcing former residents out of these areas (Van De Voorde). The introduction of legalized marijuana altered the city's trajectory and overall structure, so examining this effect is vital to understanding Denver today.

II. Historical Background

The land Denver currently sits on was home to Southern Arapaho and Southern Cheyenne Native Americans before the Louisiana Purchase in 1803. These tribes camped along the Cherry Creek River close to where it joined with the South Platte River, giving them an optimal location for hunting, trading, and bartering with other tribes and, eventually, American explorers. This location proved ideal for natives hunting bison and utilizing the watershed and for American settlers and their lust for gold. The base of the Rocky Mountains just west of Denver held hidden pockets of this fine metal that had been elusive in the new world for many decades. As a result, more and more Americans and Europeans flooded the area in the mid-19th century in search of gold, new opportunities, or pursuing "Manifest Destiny." After an influx of white settlers pushed the

Arapaho and Cheyenne from their lands, these tribes fought to maintain the land the early U.S. government preserved for them, but they had little success. On those same lands that were promised to Native Americans mere decades earlier, the settlement of Denver was established in 1858 (Leonard 3-17).

After a tumultuous turn of the century filled with the construction of railroads, high rates of crime, and population fluctuation, Denver began to invest in building community and collective efficacy. Wealthy residents like Robert Speer aided in the construction of civic centers, libraries, social clubs, theaters, and parks. These additions in the early 20th century transformed the area into a more urban city center (Leonard 71-81). However, after World War I, the growing city saw a rise of unrest, economic hardships, and prejudice, marked by the resurgence of the Ku Klux Klan and a rise in racial segregation (Leonard 82-90). Not long after, the city fell victim to the nationwide Great Depression, and all residents of Denver were affected in some capacity. They turned to the government for help, and President Roosevelt's New Deal answered their pleas. FDR's policies generated jobs for all residents of Denver and once again focused on building social capital and trust through community centers like the now-famous Red Rocks Amphitheater, as well as buildings, roads, sewage plants, and water projects (Leonard 99).

While the New Deal generated a lot of positive change in Denver, it also brought on one of the longest-lasting contributors to racial residential segregation: redlining. Roosevelt's Federal Housing Administration generated maps of cities like Denver, highlighting "at-risk," largely BIPOC, neighborhoods in red. Individuals who resided in redlined neighborhoods were denied access to loans by local banks, limiting BIPOC home ownership and future wealth creation (Kowalski). Redlined areas in Denver still maintain populations with high concentrations of poverty and racial residential segregation, and this practice shaped the city as we know it today.

World War II brought more job opportunities for Denver citizens, as many participated in building the defense with steelwork jobs or similar occupations. The economy steadily drove forward throughout the rest of the 20th Century.

Fast forward to the 2010s, Denver continued to grow rapidly, becoming one of the fastest-growing metro areas in the country. The city expanded on all sides, pushing up against the Front Range mountains and further into the plains to the east. Sophisticated highways and avenue systems have made the city more accessible, as well as a comprehensive public transit network with RTD. The Denver economy was also steadily climbing. Denver focused on the environmental wonders, acclaimed breweries, and successful sports teams that brought in tourism to promote economic growth (Leonard 185-190).

A significant factor that has contributed to Denver's economic growth in recent years was Colorado's vote to legalize marijuana in 2012. Marijuana has become an important business in Denver, with almost four hundred grow operations feeding around two hundred metro-area retail outlets, and this number is growing exponentially every year (Leonard 191). Legalization has completely changed the structure of the city. Places that used to be hotbeds for illegal drug use and activity are now being gentrified and invested in due to Denver's newest commodity. The stigma around drug use has been all but erased, so many areas previously avoided due to a reputation for drug activity are now wealthy, young, and thriving due to this change in legislation (Van De Voorde).

Today, the effects of this history are omnipresent around the city of Denver. Each piece of Denver's past could be analyzed in a report similar to this one, but a few elements are more striking when looking at the city in 2023. Understanding the impact of redlining is vital in order to understand concentrated disadvantage in Denver as well as racial residential segregation. Redlining also lead to the pockets of drug-related crime in the early 21st century that are important to the story of gentrification in Denver. These formerly over-policed areas are now the locations of some of the most high-end and trending places in Denver, in a large part due to the growing marijuana business in the city after legalization. All of these pieces contribute to the structure of Denver today, so I will attempt to understand just how big of an impact each has had in the report below.

III. Questions and Key Variables

The key questions I am examining in this report are as follows: In what ways did historical redlining shape concentrated poverty and racial residential segregation in Denver in 2009/2010? Were these redlined areas predictive of where marijuana drug arrests were concentrated before legalization? And finally, how do marijuana-related drug arrests in the past predict gentrification in Denver today?

The key variables I am analyzing to explore these questions are the percent of residents living in poverty in a given census tract, the percent of residents who are white in a given census tract, historical redlining scores for each tract, and marijuana related arrests across the city. For the first two key variables, I have pulled data from American Community Survey five-year estimates from Social Explorer, along with other variables that could confound the relationship between my key variables (Social Explorer). I utilized data from 2009 and 2018 because they were the closest 5 year estimates from the 2012 legalization in Colorado and more recent years without skewed data due to the COVID-19 pandemic. I received the historical redlining data from IPUMS National Historical Geographic Information System, and I pulled the marijuana crime data from Denver's Open Data Catalog (Steven Manson, City of Denver).

IV. Data Upload and Basic Visualizations

Here I will load the packages necessary to complete this analysis.

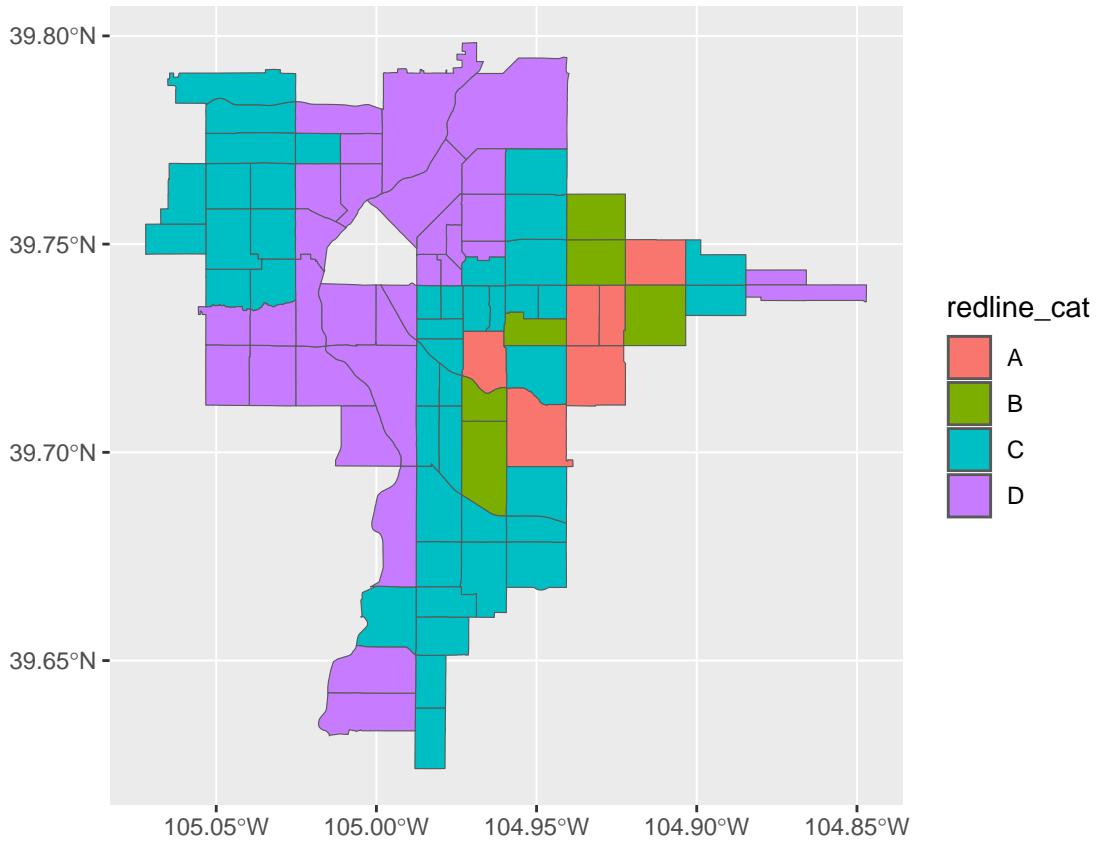
Data Upload

Here I will load the packages necessary to complete this analysis. Next, I will read in the shapefile for Denver and the two years of ACS data, which are 2018 and 2009. I will then select the variables I wish to include for both years and join these together to create one data frame, and then join the redlining data and marijuana-related crime data to this data frame.

Basic Visualizations

2009 Visualizations

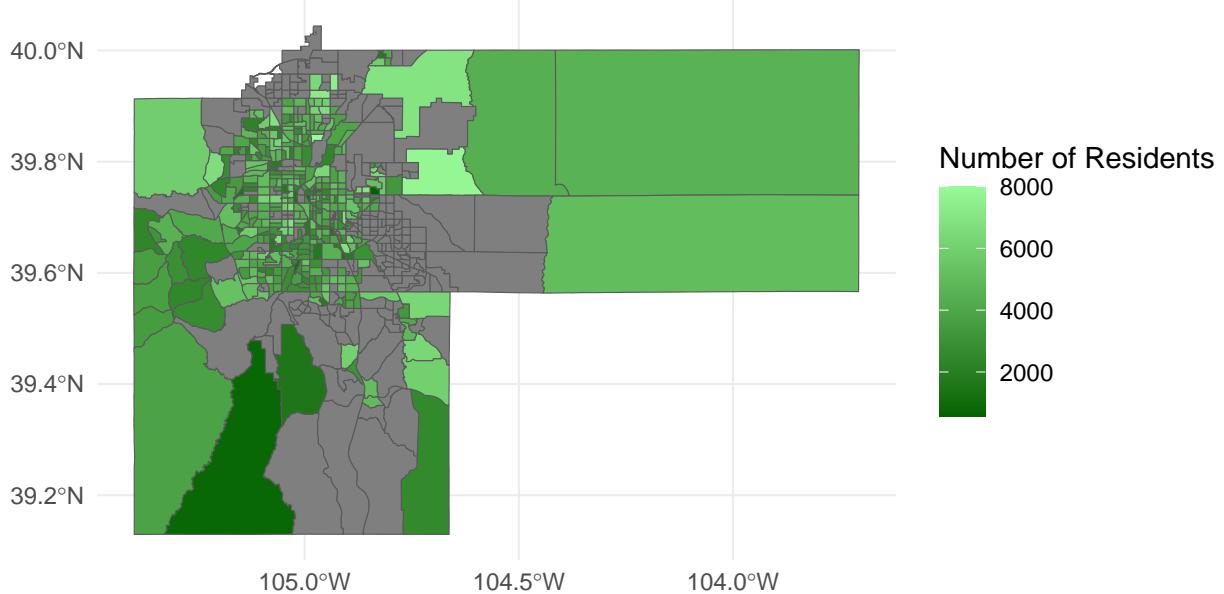
Historic Redlining Visualization



This map visualizes the red line scores of different census tracts in Denver, with D being the areas that were labelled at risk in the 1930s. This map places those scores onto the 2010 census tract map so it is easier to compare to the rest of our visualizations from 2009 and 2018. It appears that very few tracts still being used by the census were given A or B scores, as most of this map appears to be in the C or D category. Because of this, we can infer that many parts of Denver's inner-city were populated by racial minorities or heavily impoverished communities during the time when redlining was first taking place, causing the inner-city to be full of D and C level tracts. This visualization is the beginning of the data portion of this report because subsequent visualizations will demonstrate that the redlined areas in this map continued to be tracts with low percentages of white residents, high percent poverty, and low median household incomes. Thus, it can be inferred that historical redlining created the structure of the city so absolutely that the effects are still causing concentrated disadvantage in Denver in more recent years.

Total Population Map

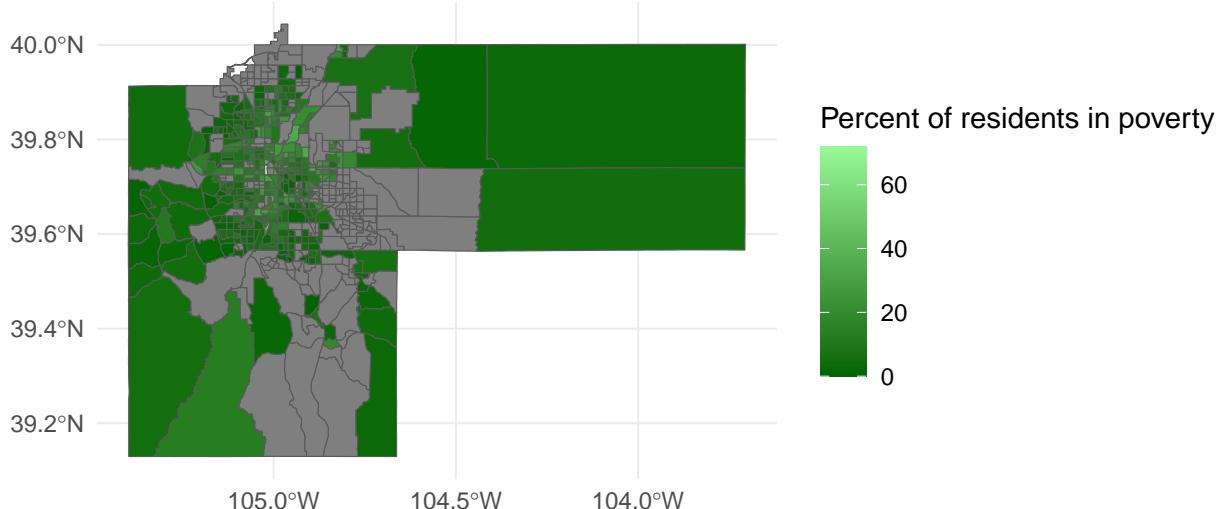
Total Population Map 2009



This map shows that the city had a much smaller total population in 2009 than in 2018. The residents are pretty evenly spread across the urban and more rural areas of Denver, with many of the tracts having between 4,000 and 6,000 residents. There are pockets of lower and higher population sizes in different tracts, with the tracts on the upper right side of the city having the highest concentration of residents with around 8,000. The lower left side of the city has the lowest concentration of residents, as it has less than 2,000 residents. These patterns in population concentration could be due to the fact that Denver had a much smaller population in 2009, as it grew exponentially throughout the 2010s (Leonard). The missing tract data could also be due to this fact, as this shapefile is taken from the 2010 census tracts.

Percent Living in Poverty

Percent Living in Poverty 2009 Map

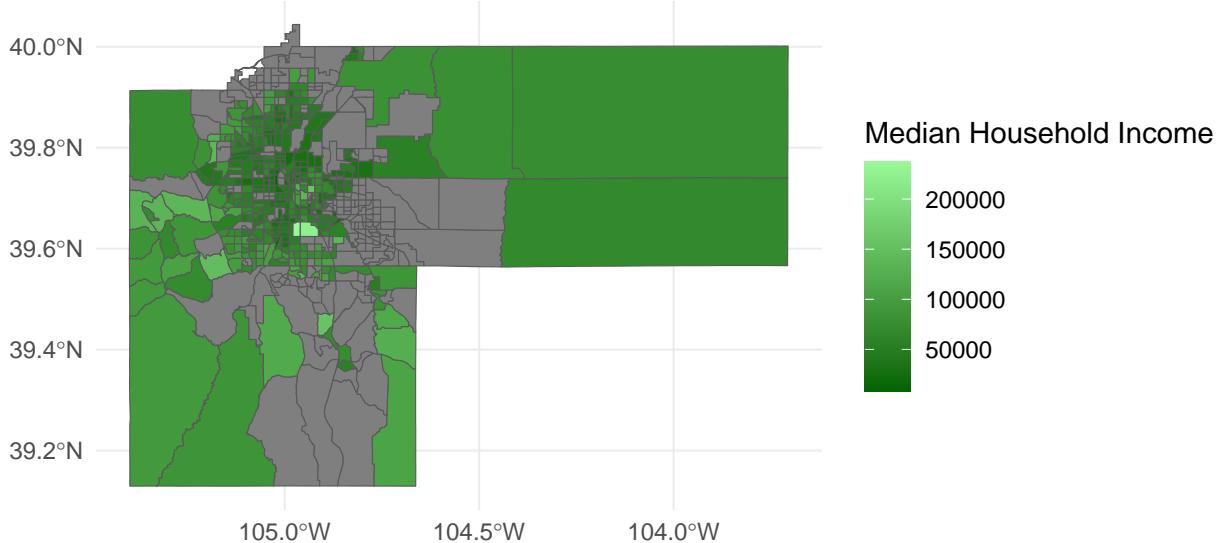


In this map, there appears to be a larger cluster of high poverty tracts in the center of Denver, whereas the rest of the city appears to have less than 20% of residents living in poverty. This follows the pattern demonstrated in the redlining map that shows that inner-city neighborhoods are more disadvantaged in Denver due to historical redlining, as many of these areas have more than 60% of residents living below

the poverty line. The high concentration of poverty in these areas is a appears to be somewhat a result of the discrimination within the redlining process in the past, showing that redlining still heavily impacts the composition in Denver in more recent years, especially with concentrated poverty (Kowalski). There appears to be more high poverty tracts in this map compared to the 2018 map, showing that more recent developments and investments into different areas have changed the poverty levels in places that have been historically disadvantaged. This could be due to gentrification, which will be discussed later in

Median Household Income Map

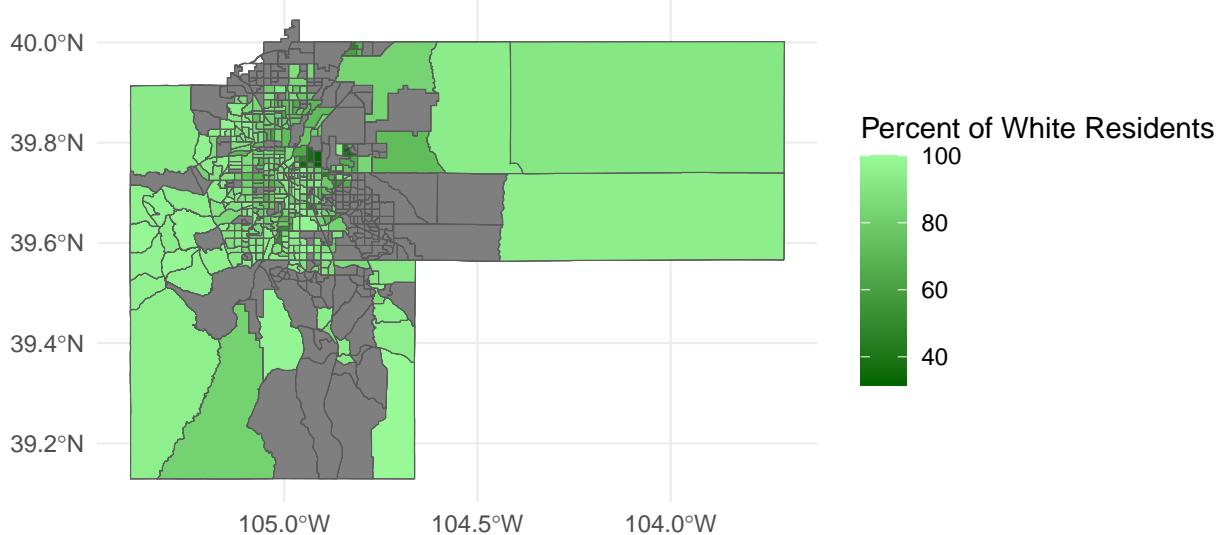
Median Household Income Map 2009



This map provides another visualization of how wealth was distributed across Denver in 2009. Instead of measuring the percent of residents living below the poverty line, this map shows the median household income in the different census tracts across Denver. As demonstrated on the map, many census tracts have relatively similar median household incomes, with most being at around 100,000 to 150,000 dollars a year. However, there are clusters with lower median household incomes that are more central on the map. These tracts align with those with higher poverty levels and fewer white residents, meaning more poverty and less white residents in a given tract correlates to a lower median household income for that tract. These areas are also the same tracts that were considered “at-risk” in the historical redlining map. Because of this, we can infer that historical redlining in some way causes these pockets to persist over time. On the other hand, there is also a cluster of tracts with high median household incomes, containing tracts with more than \$200,000 a year. These areas are likely those that were heavily invested in during the expansion of Denver by benefactors like Robert Speer, who created the Denver Country Club and the surrounding area that remains one of the wealthiest and whitest neighborhoods in Denver even today (Leonard).

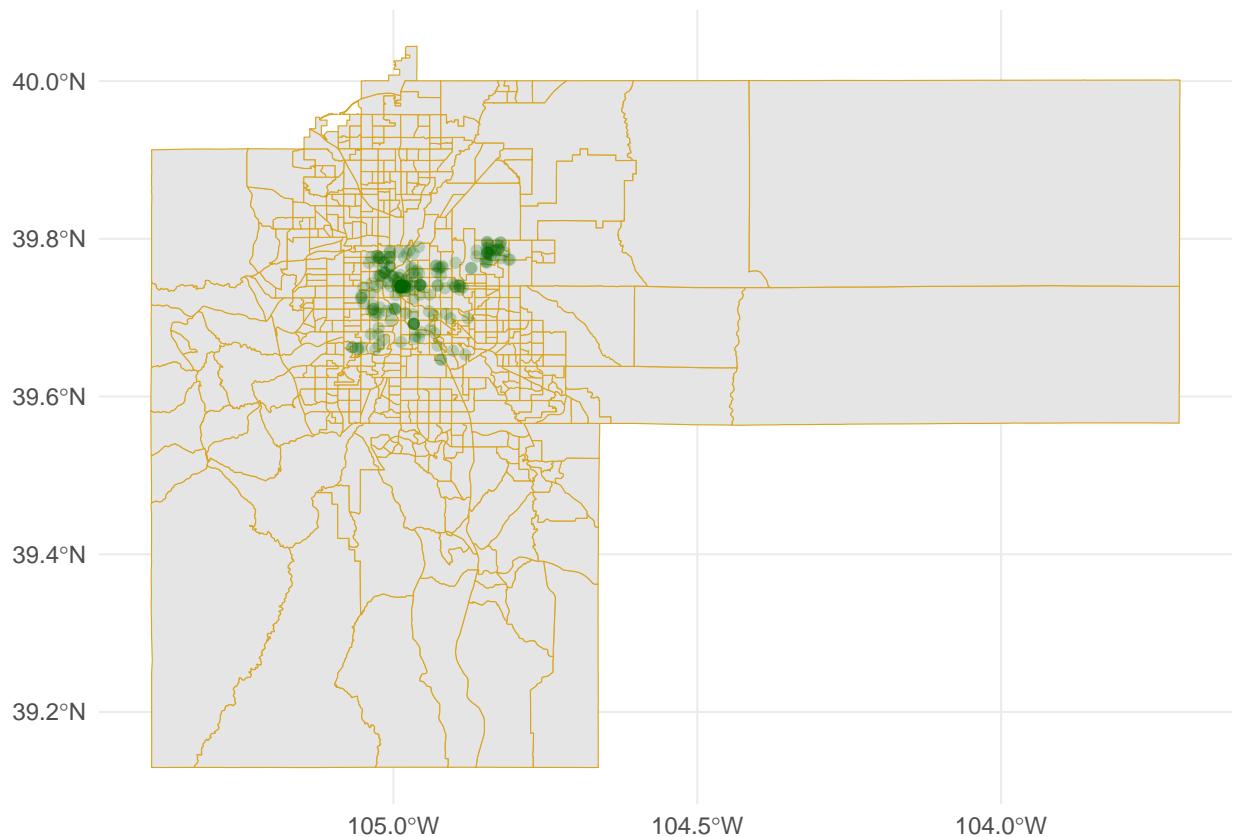
Percent White Map

Percent White Residents Map 2009



This map shows that Denver had a very high concentration of white residents in most tracts in 2009. The majority of the census tracts in this map have populations that are between 80 and 100% white. As you move closer to the center of the city, more tracts seem to have more diverse populations, with the majority having between 60 and 80% white residents. In the very center of Denver, there is a cluster of tracts that are around 40% white or lower, which indicates that the residents in this tract are people of color. The patterns seen in this map align with the pattern of redlined tracts demonstrated above. This means that areas that were labeled “at-risk” in the past are still more heavily populated by diverse residents in 2009, as many tracts that were labeled “at-risk” were given this classification because of the population was full of people of color (Kowalski). This means that, at least from this surface level, redlining patterns predict racial residential segregation in 2009.

2010 Marijuana Related Crimes



This map leads to the next piece of my evaluation of Denver, which includes the analysis of marijuana-related drug arrests before legalization. As previously mentioned, the state of Colorado voted to legalize marijuana in 2012, so this map of 2010 records the marijuana-related arrests 2 years before legalization. As seen on the map, the marijuana-related drug arrests are highly concentrated across tracts in Denver's inner-city neighborhoods. These neighborhoods appear to be the same as or close to the tracts that were considered "at risk" in the historical redlining data, meaning that the categorization of these tracts, for one reason or another, could have led to more arrests in these areas. Similarly, these tracts are also those that had high concentrations of poverty and lower percentages of white residents in 2009, meaning these neighborhoods were impoverished and containing larger minority populations than other tracts in Denver. The high concentration of drug arrests in these areas could be due to an increased police presence in the area because of this categorization or due to heightened drug activity because of the concentrated disadvantage in these areas. Regardless of the reason, there appears to be a link between historically redlined tracts and drug arrests pre-legalization in Denver.

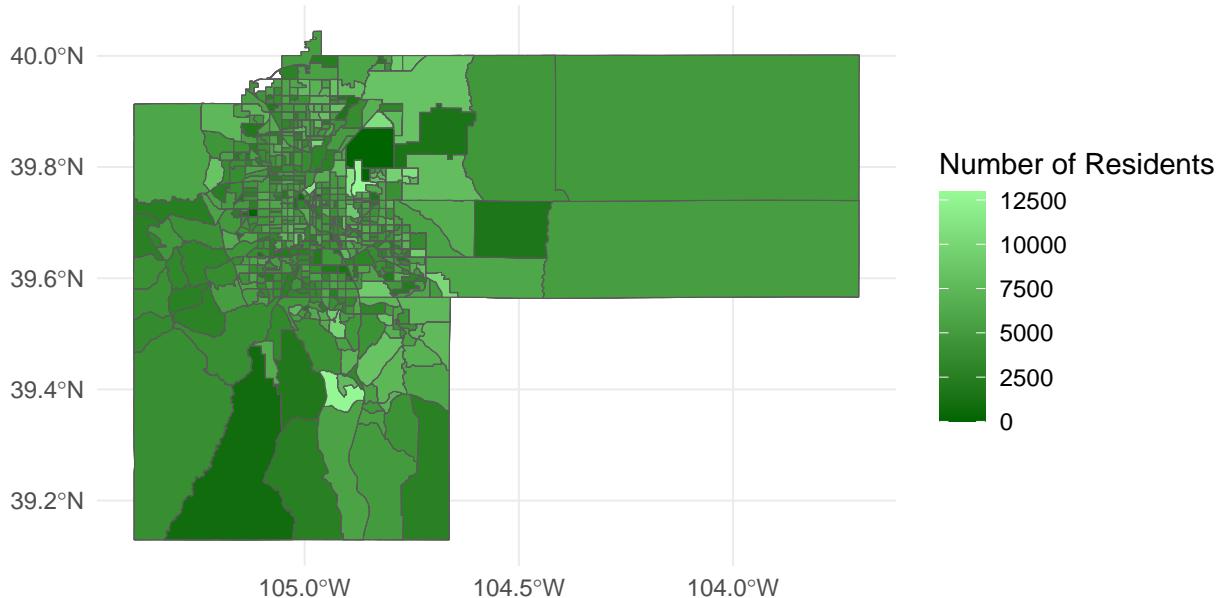
2018 Comparison Visualizations

After legalization of marijuana, the areas highlighted as impoverished, more diverse, and having a high concentration of marijuana-related crimes in 2009, and historically in the redlining map, appear to have slowly gentrified. Young, wealthy, white residents began flooding these areas, as these tracts now contain Denver's hottest economic driver: marijuana dispensaries. Legalizing marijuana has altered the city in many ways, one being increased housing values in areas where dispensaries and usage is widespread. In fact, this new policy has improved housing values by an estimated 6%, which translates to about \$16,000 per property (Cheng). Increased housing values likely drive lower-income renters and homeowners out of these areas because they can no longer afford rent or related prices. Similarly, new construction projects, renovation of historic buildings, and an increase of luxury dining, retail, and other experiences have caused an influx of wealthy residents to purchase or rent housing in these areas, again forcing the former residents of these tracts out do to increased prices (Prentiss). In the visualizations below, the effects of gentrification due to these drivers are clear, as the clusters of concentrated disadvantage seen in the 2009 visualizations decrease in size

and severity in almost all cases.

Total Population Map

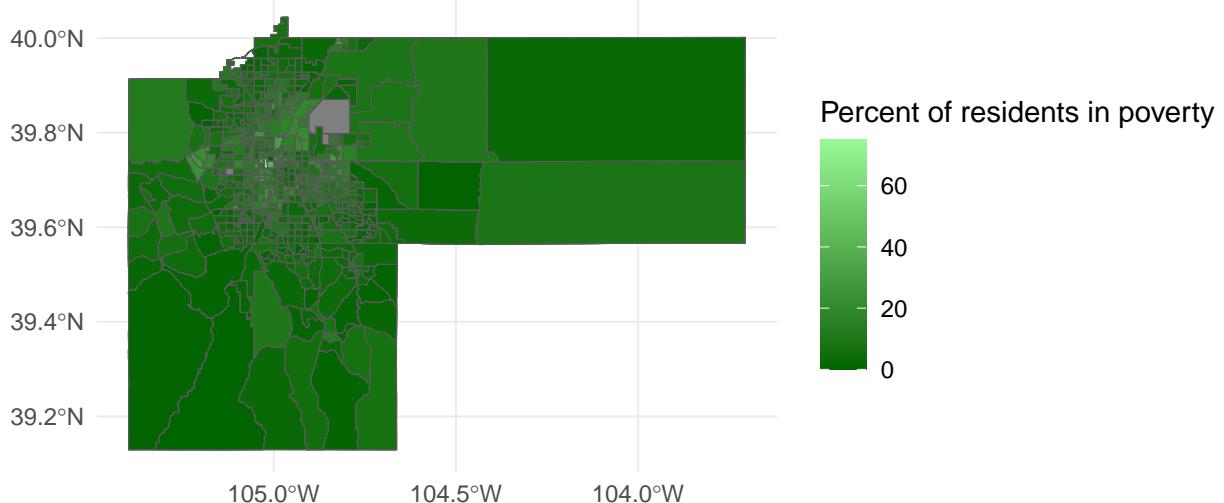
Total Population Map 2018



This map demonstrates the exponential growth of Denver in the 2010s, as the population has increased dramatically since 2009. The concentration of the population has also shifted. The population in 2018 seems to be heavily concentrated in a few smaller subsections of this map that are fairly central in the Denver area or just outside of it in more suburban areas. Many of the tracts with greater populations are grouped together, showing that there is clustering in Denver based on populations who share similar concentrations of residents. It appears to be far less concentrated on the outskirts of the city than in 2009, with the total population of these areas differing greatly to those more central in the Denver area. However, the lower left-hand side of the map still appears to have the lowest concentration of residents with less than 25,000, and the upper right-hand side appears to still have the highest concentration of residents, with some tracts having up to 125,000 residents. The tracts that have the highest number of residents in the upper right side appear to have shifted inwards slightly, suggesting that more people are living in the suburbs just outside of the more urban area in 2018 than in 2009.

Percent Living in Poverty Map

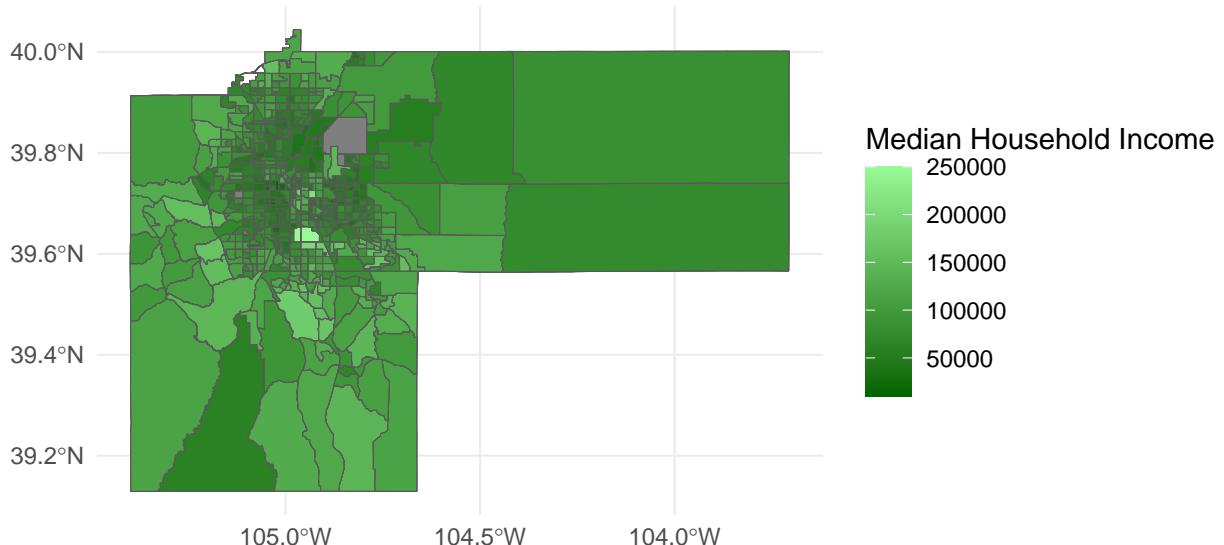
Percent Living in Poverty Map 2018



This map demonstrates that the percentage of residents living below the poverty line in Denver has decreased from 2009 to 2018. The tracts on the outsides of the city have very low percentages of residents living in poverty, with many having close to 0%. The tracts in the center of the city appear to have lower percentages of residents living in poverty as well, as only a few tracts have more than 20-40% of residents living in poverty. These tracts had higher percentages in 2009 by almost 20%, so it is clear that poverty rates have decreased in these tracts in the last decade. However, one tract at the center of this map has around 60% of residents living in poverty, which is a similar to its percentage in 2009. This tract's percentage of impoverished residents has not changed as dramatically as others surrounding it, indicating that there is still high concentrated disadvantage in Denver's most inner-city tract/neighborhood. It does appear to have decreased slightly, but not nearly as much as the tracts clustered around it. Nonetheless, this map as a whole demonstrates that the changes in investment and policies in Denver has led to a overall decrease in poverty, aligning with the patterns of gentrification I theorized about in the beginning of this report.

Median Household Income Map

Median Household Income Map 2018

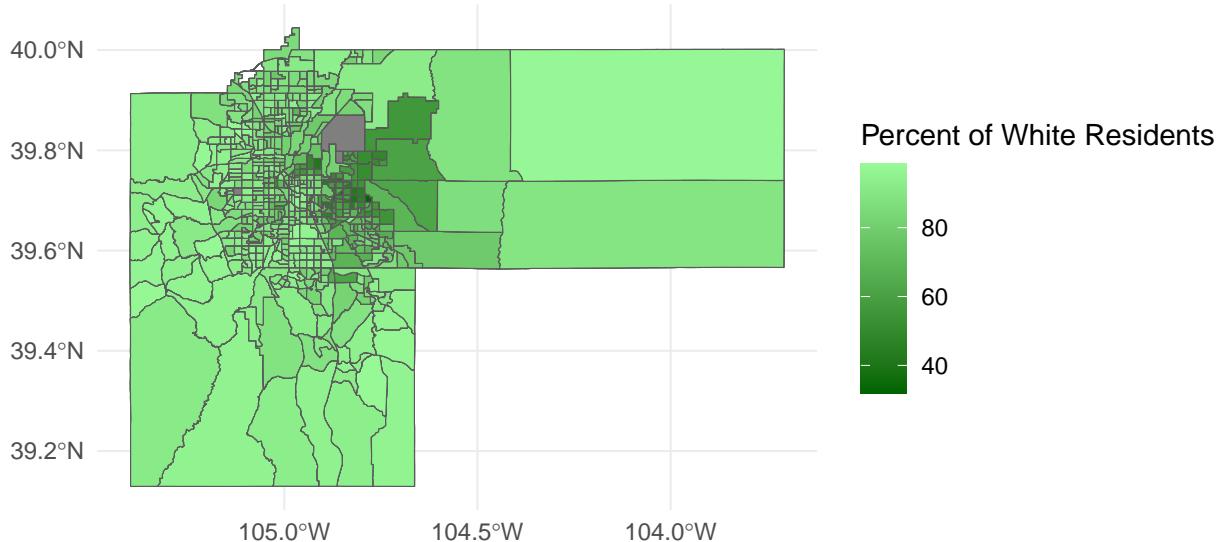


This map shows the median household income in 2018 in Denver. When compared to the 2009 visualization, almost all of the tracts in Denver have increased their median household income in the last decade. Many

who were falling in the 100,000 - 150,000 dollar mark now have a median household income of nearly 200,000 - 250,000 dollars. Denver's inner-city also shows significant increases in median household income. Many tracts in this area had median household incomes of \$50,000 in the previous map, and here they have closer to \$100,000. This change is another indicator that poverty has decreased in Denver since 2009 and overall income has increased. Residents in areas that were previously full of impoverished and low-earning residents are now earning almost double than what they were before, again showing that the changes in legislation, investment, and overall growth of population in the 2010s had lead to wealthier residents due to gentrification.

Percent White Residents Map

Percent White Residents Map 2018



This map indicates the percentage of white residents in 2018 in Denver's census tracts. Over the past decade, the white population in Denver appears to have increased in all tracts. Although Denver already contained a large population of white residents in 2009, some tracts still maintained a population that was less than 40% white. In 2018, these tracts all appear to have at least 60% white residents, meaning that they have become less diverse, or populated by people of color, overtime. Some tracts that were not represented on the 2009 visualization due to missing data or because the tract did not exist yet have lower percent white populations than the rest of the city, but these are very limited. Overall, it appears that Denver has become increasingly more white between 2009 and 2018 in all tracts, showing that the changes prompted by both the legalization of marijuana and the investment into different neighborhoods has led to gentrification in Denver.

V. Exploratory cross-sectional regressions

OLS - Background Models

These OLS regression models demonstrate that there is a relationship between percent white and percent poverty in and across the two years I am analyzing. They predict this relationship without the inclusion of two key variables in my report: historical redlining score and number of marijuana-related crimes, but they show the foundational relationship between these variables that will be further broken down in the next section.

Analysis

These models show the relationship between the percentage of white residents in a given tract and the percentage of residents living in poverty in this same tract at two distinct places in time. It also holds constant variables that could create bias in the estimate of this relationship. All of these models provide the

	Model 1	Model 2	Model 3	Model 4
(Intercept)	28.209(1.484)*** (1.484)	8.162(0.712)*** (0.712)	-0.590(0.226)** (0.226)	47.712(1.306)*** (1.306)
percent.white09	-0.297(0.013)*** (0.013)			0.471(0.014)*** (0.014)
percent.unemployed09	1.152(0.064)*** (0.064)		0.187(0.045)*** (0.045)	0.195(0.069)** (0.069)
percent.HS09	0.136(0.016)*** (0.016)			
percent.moved2005orlater09	0.002(0.009) (0.009)			
percent.white18		-0.100(0.007)*** (0.007)		
percent.unemployed18		1.727(0.022)*** (0.022)	1.781(0.021)*** (0.021)	-1.017(0.033)*** (0.033)
percent.HS18		0.140(0.010)*** (0.010)		
percent.moved2015orlater18		0.017(0.010) (0.010)		
percent.pov09			0.281(0.011)*** (0.011)	
Num.Obs.	3758	5326	3751	3751
R2	0.320	0.636	0.729	0.393
R2 Adj.	0.319	0.636	0.729	0.393
AIC	26 868.2	34 700.6	24 072.0	27 525.5
BIC	26 905.6	34 740.1	24 103.2	27 556.7
Log.Lik.	-13 428.080	-17 344.304	-12 031.015	-13 757.769
F	441.481	2326.248		
RMSE	8.62	6.28	5.98	9.48

background for my analysis, as they show that there is a correlation between these two variables in 2009 and 2018 and across these two time-points as well. However, they do not show the causes for this relationship, which will be analyzed in the next series of models.

According to Model 1, as percent poverty rises in 2009 by one unit value in an area, the percent white in 2009 in that area goes down by 0.297 with a standard error of 0.013, meaning this coefficient is statistically significant. The AIC for this model is 3444.7 and the BIC is 3469.8, which are the second smallest of these values across all of our OLS models in this summary. However, the AIC and BIC for all of these models is very similar, meaning that these models fit the data in similar ways.

According to Model 2, as percent poverty rises in 2018 by one unit value, percent white in 2018 decreases by 0.100, with a standard error of 0.007, meaning it this coefficient is statistically significant and precise. This tells us that percent white decreases less in 2018 than in 2009, at least according to our models, alluding to the theory that gentrification has caused the minorities living in Denver to be pushed out of their original tracts or neighborhoods, leading to all areas of the city becoming whiter. The AIC for this model is 4520.3 and the BIC is 4547.5, which is slightly higher than the other models in this section, meaning this model might not fit the data as well as others included here.

Model 3 demonstrates that, as percent poverty rises in 2009 by one unit value, percent poverty in 2018 increases by 0.281, with a standard error of 0.011, meaning this coefficient is statistically significant and precise. This model tells us that the tracts that had high poverty rates in 2009 are indicative of the tracts that will have high poverty rates in 2018, meaning that impoverished areas in 2009 predict impoverished areas in 2018. This demonstrates that the pockets of poverty in Denver are still present, even as the demographics and racial composition of these places are changing and as gentrification continues to alter the city's structure. The AIC of this model is 3407.3 and the BIC is 3428.2, which are the smallest of these values across all four fitted models. However, as mentioned previously, these values are still relatively similar to all others, making their fit to the data all virtually the same.

According to Model 4, as percent white increases in 2009 by one unit value, percent white in 2018 increases by 0.471 with a standard error of 0.014, meaning this coefficient is statistically significant and precise. This indicates that the tracts with high percentages of white residents in 2009 will continue to have high percentages of white residents in 2018, meaning percent white in 2009 is very predictive of percent white in 2018. This means that areas are remaining very white in Denver or even getting whiter overtime, again highlighting the theory that gentrification is lessening the diversity in Denver over time. The AIC of this model is 3582.0 and the BIC is 3602.9, which is fairly similar to the other models in this section.

All of these models indicate that whiter areas in Denver have less residents living in poverty, but they are missing many factors that could better represent this relationship and make it more accurate. One thing missing from these models is space. Space and the spatial relationship between tracts is in the error term as is everything else there is to know about this "world". Because of this, this model does not include the possible spill over between different tracts. However, after running these models while working on this project, I found that the spatial spillover between tracts, while it does exist, does not significantly effect the results of the relationship I am trying to measure and analyze in these models. These models also do not include the causes for the percent white and percent living in poverty, which, according to my analysis, are historical redlining and marijuana-related crimes, and these variables will be included in the models to demonstrate the change in relationships between percent white and percent poverty below.

OLS - Drug Crimes and Redlining Models

```
## Correlation tests
## Call:r.test(n = 3751, r12 = c1, r34 = c2)
## Test of difference between two independent correlations
## z value 0.58 with probability 0.56
```

The function r.test tests the significance of the correlations between percentage of residents living in poverty in 2009 and 2018 and the number of marijuana related drug crimes in these areas in 2010 before marijuana was legalized. This test shows us that the difference between these coefficients is not statistically significant,

meaning we cannot draw a strong conclusion as to whether they are statistically significantly different or not based on this model. This relationship is explored further in the below regression models as well as visually in visual exploratory models.

Analysis

These models are attempting to predict marijuana-related drug arrests and redline scores based on the percentage of residents living in poverty in 2009 and 2018. For the marijuana-related crimes, I am running this model to demonstrate that poverty in areas with more drug crimes before legalization will be higher or more correlated than in these same areas after legalization. I expect there to be a correlation between percent poverty and number of drug crimes in both 2009 and 2018, but the correlation should decrease over time due to the gentrification that occurred post-legalization in the 2010s, causing less poverty in these tracts. For redline scores, I am attempting to demonstrate that the correlation between the historical redline scores and the percentage of residents living in poverty decreases from 2009 to 2018, again due to gentrification in Denver throughout the 2010s.

I acknowledge that it is unusual to use a response variable, in this case number of drug crimes and historical redlining scores, that occurs before the predictor variables in time, but I am not trying to predict the outcome for these variables. Here, I am attempting to highlight the correlation that already exists through running a regression that seemingly flows backwards in time in order to demonstrate that redlining scores and number of marijuana-related crimes do in fact predict poverty and percent white in different tracts at different points in time, as well as other variables with significant results that are not discussed at length in this paper. While this approach does not follow typical form, it is intentional so I can attempt to demonstrate ideas that would be otherwise more difficult to describe.

Model 1 demonstrates the correlation between the number of marijuana-related drug crimes in a given tract and that tract's percentage of residents living in poverty in 2009. It also controls for variables that could effect the coefficient of this relationship. According to this model, as the number of drug crimes rise by one unit value in a given tract, the percent poverty rises by 0.043, with a standard error 0.007, meaning this value is precise and statistically significant. The AIC for this model is 20578.0 and the BIC is 20621.6, which are the lowest of these values in this set of regressions, meaning this model fits our data well.

Model 2 demonstrates the correlation between the number of marijuana-related drug crimes in a given tract and that tract's percentage of residents living in poverty in 2018. Similar to model 1, this model controls for variables that could impact this relationship, and there were more variables in the 2018 census data that altered this coefficient than in 2009. This model shows us that as the number of drug crimes increases by one unit value, the percent poverty in that tract rises by 0.035, with a standard error of 0.008, meaning this value is precise and statistically significant. Model 06 reinforces my theory that tracts with more drug crimes in 2009 have less poverty in 2018 due to gentrification after the legalization of marijuana, as the correlation between number of drug crimes and poverty in 2018 is less than that for poverty in 2009, meaning these crimes are less predictive of poverty after legalization. I will further explore this result and correlation in visual models in the next section.

Model 3 shifts out focus from marijuana crimes to redlining scores, demonstrating the relationship between the redline scores of a given tract and the percentage of residents living in poverty in that same tract. According to model 3, as the redlining score rises, meaning it decreases from 1 to 5, with 5 being the label for "at-risk" tracts, the percentage of residents living in poverty increases by 0.011 in 2009, with a standard error of 0.002, meaning this value is statistically significant and precise. Because of this, we can determine that there is a correlation between low redlining scores and higher poverty in Denver for 2009, as this coefficient is positive and significant. Thus, historical redlining scores appear to be predictive of tracts with high poverty in 2009, as theorized in the beginning of this report. This model also tells us that, as a tract's redlining score decreases, the percentage of white residents in that tract actually increases by 0.009, with a standard error of 0.002, meaning this is statistically significant and precise. This contradicts my theory that the redlined tracts in Denver were highly concentrated areas of poverty and BIPOC, but this model suggests this might not be the case. However, Denver was already a considerably white city in 2009, so almost every tract was over 80% white. This concentration of white residents in general as a whole could lead to this result, or it could

	Model 1	Model 2	Model 3	Model 4	Model 5
(Intercept)	0.963(0.669) (0.669)	0.164(0.387) (0.387)	1.549(0.183)*** (0.183)	2.143(0.167)*** (0.167)	1.836(0.179)*** (0.179)
percent.pov09	0.043(0.007)*** (0.007)		0.011(0.002)*** (0.002)		
percent.unemployed09	-0.027(0.029) (0.029)		0.057(0.007)*** (0.007)		0.071(0.007)*** (0.007)
percent.HS09	-0.007(0.007) (0.007)		0.030(0.002)*** (0.002)		0.032(0.002)*** (0.002)
percent.moved2005orlater09	-0.008(0.004)+ (0.004)		-0.001(0.001) (0.001)		-0.001(0.001) (0.001)
percent.white09	0.002(0.006) (0.006)		0.009(0.002)*** (0.002)		0.006(0.002)*** (0.002)
percent.pov18		0.035(0.008)*** (0.008)		0.003(0.003) (0.003)	
percent.unemployed18		-0.030(0.018)+ (0.018)		0.003(0.006) (0.006)	
percent.moved2015orlater18		0.002(0.005) (0.005)		0.010(0.003)*** (0.003)	
percent.nonfam18		0.032(0.003)*** (0.003)		0.018(0.001)*** (0.001)	
percent.HS18		-0.036(0.006)*** (0.006)		0.039(0.003)*** (0.003)	
percent.nohealth18		0.016(0.009)+ (0.009)		0.040(0.004)*** (0.004)	
percent.white18		-0.005(0.004) (0.004)		-0.011(0.002)*** (0.002)	
n_drugcrimes					0.010(0.003)*** (0.003)
Num.Obs.	3758	5326	1327	1351	1327
R2	0.012	0.065	0.289	0.480	0.271
R2 Adj.	0.011	0.063	0.287	0.478	0.268
AIC	20 540.0	27 080.9	2558.5	2174.1	2592.0
BIC	20 583.7	27 140.1	2594.8	2220.9	2628.3
Log.Lik.	-10 263.018	-13 531.453	-1272.256	-1078.030	-1288.999
F	9.388	52.569		177.354	
RMSE	3.71	3.07	0.63	0.54	0.64

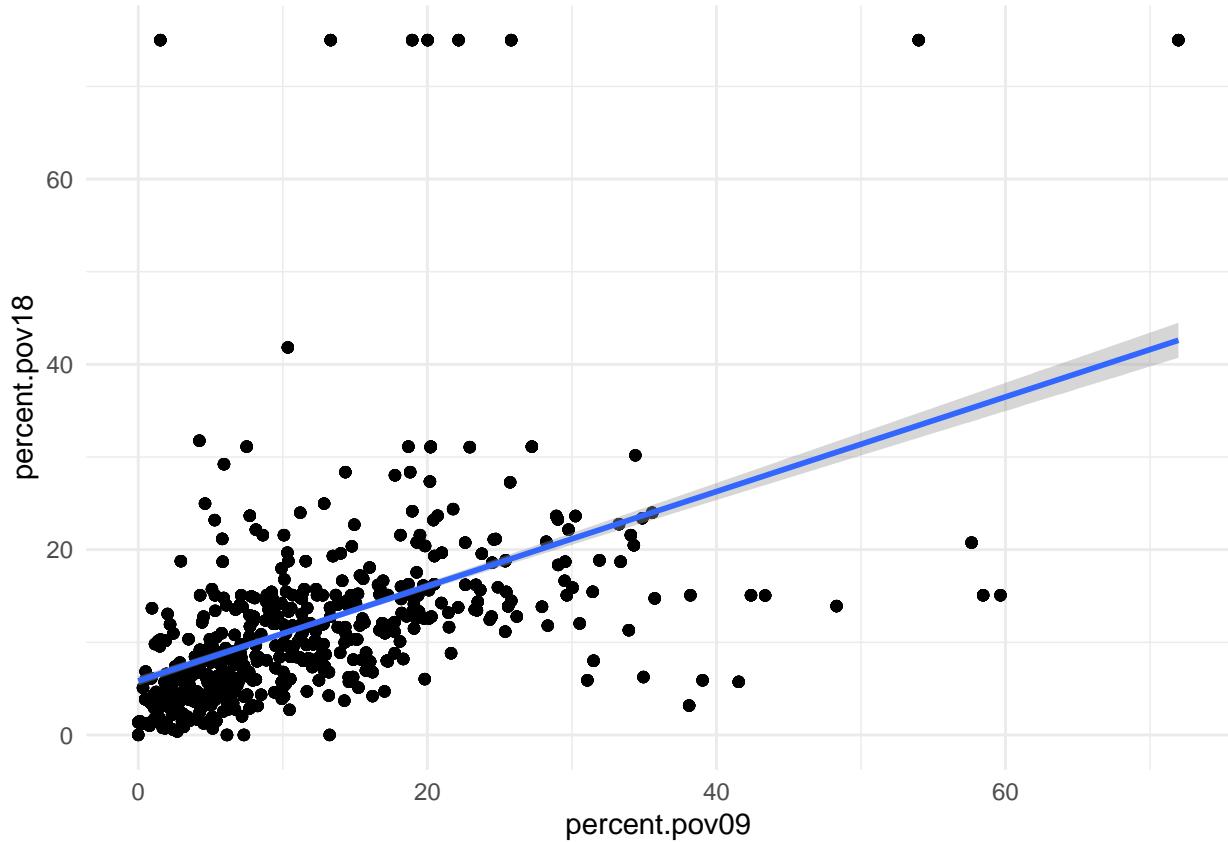
be due to missing data in the redlining tracts. Many of the other coefficients included in this model are also interesting and statistically significant, showing that redlining scores have an impact a variety of different neighborhood effects in 2009.

According to model 4, as the redlining score moves from 1 to 5 and worsens, the percentage of poverty increases by 0.003 in 2018, with a standard error of 0.003, meaning this value is not statistically significant or precise. Because of this, we cannot say for certain that the redlining scores are correlated to the percentage of residents living in poverty for a given tract because our coefficient is not statistically significant. When we look at the coefficient alone, there is a positive correlation, and it is less than the coefficient seen in the 2009 model. This means that as redlining scores worsen, poverty increases in 2018, but due to the standard error we cannot say that this is certain. The high standard error on this coefficient could be due to missing data and the exponential growth of Denver in the 2010s, leading to more census tracts being formed that do not have historical redlining scores. This model also tells us that, as redlining scores decrease and move from 1 to 5, the percentage of white residents in that tract decreases by -0.011, with a standard error of 0.002, meaning this is statistically significant and precise. This coefficient demonstrates that fewer white residents lived in impoverished areas in 2018 than in 2009, indicating that the areas with high concentrations of white residents were wealthier in 2018. This finding reinforces my theory that gentrification altered the composition of Denver throughout the 2010s, as more white people transformed the majority of the impoverished clusters in Denver through investment in the community and demand for more economic drivers like marijuana dispensaries. Therefore, there were fewer impoverished areas in 2018 than in 2009, and those that remained had fewer white residents than those in 2009. Similar to the previous model, many of the other coefficients included in this model are also interesting and statistically significant, showing that redlining scores have an impact a variety of different neighborhood effects in 2018.

Model 5 describes the relationship between a tract's historical redlining score and the number of marijuana-related crimes in that tract in 2010. According to this model, as the redlining score worsens in a tract, meaning it goes from 1 to 5 and moves toward the "at-risk" category, the number of drug crimes in that tract increases by 0.010, with a standard error of 0.003, meaning this value is statistically significant and precise. This means that tracts with lower historical redlining scores will likely have more marijuana-related crimes in 2010 than those with better scores. We now can see that, at least according to this model, historical redlining scores predict the number of marijuana-related drug crimes in a tract later in history, which aligns with my theory introduced earlier in this report. Not only do historical redlining scores predict where concentrated poverty and racial residential segregation appears in Denver in 2009, but it also indicates that these areas will also have higher numbers of marijuana-related crimes, which makes them ideal places for gentrification after the legalization of marijuana, as the demand for this product begins in these areas.

VI. Exploratory models of change over time

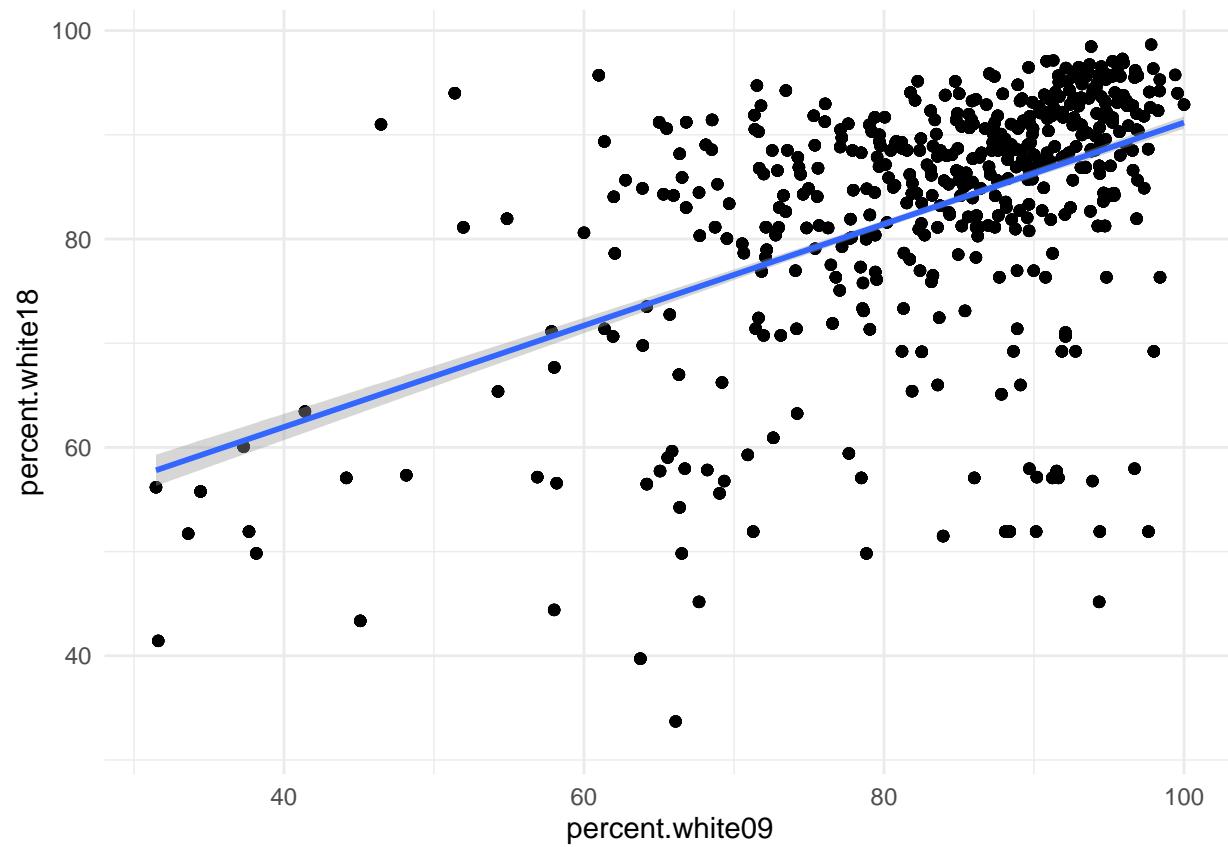
Percent of Residents Living in Poverty Change Over Time



Analysis

This visualization demonstrates the relationship between percentage of residents living in poverty in 2009 and in 2018. According to this plot, percentage living in poverty in 2009 predicts percentage living in poverty in 2018, and this relationship appears to be relatively strong and linear. However, there appear to be many tracts that had high poverty rates in 2009 that experienced a dramatic decrease of poverty by 2018. Some of these tracts had up to 60% of residents living in poverty in 2009, and less than 20% of residents living in poverty in 2018, showing that many high poverty areas experienced a dramatic decrease in poverty throughout the 2010s. Further, few tracts experienced an increase in poverty from 2009 to 2018, and those who did increased by 10% on average, showing that, on average, poverty across the city either remained stagnant or decreased between these two points in time. The increase in poverty in some areas could be due to the missing data in the 2009 tracts, as many tracts in 2009 did not have poverty data, or due to the fact that many tracts that appear in the 2018 data did not exist in 2009. Nonetheless, these dramatic decreases in poverty between 2009 and 2018 align with my theory that, after the legalization of marijuana, Denver dramatically gentrified and heavily invested in high poverty areas, especially those with high concentrations of drug crimes, as they contained the biggest demand for marijuana dispensaries.

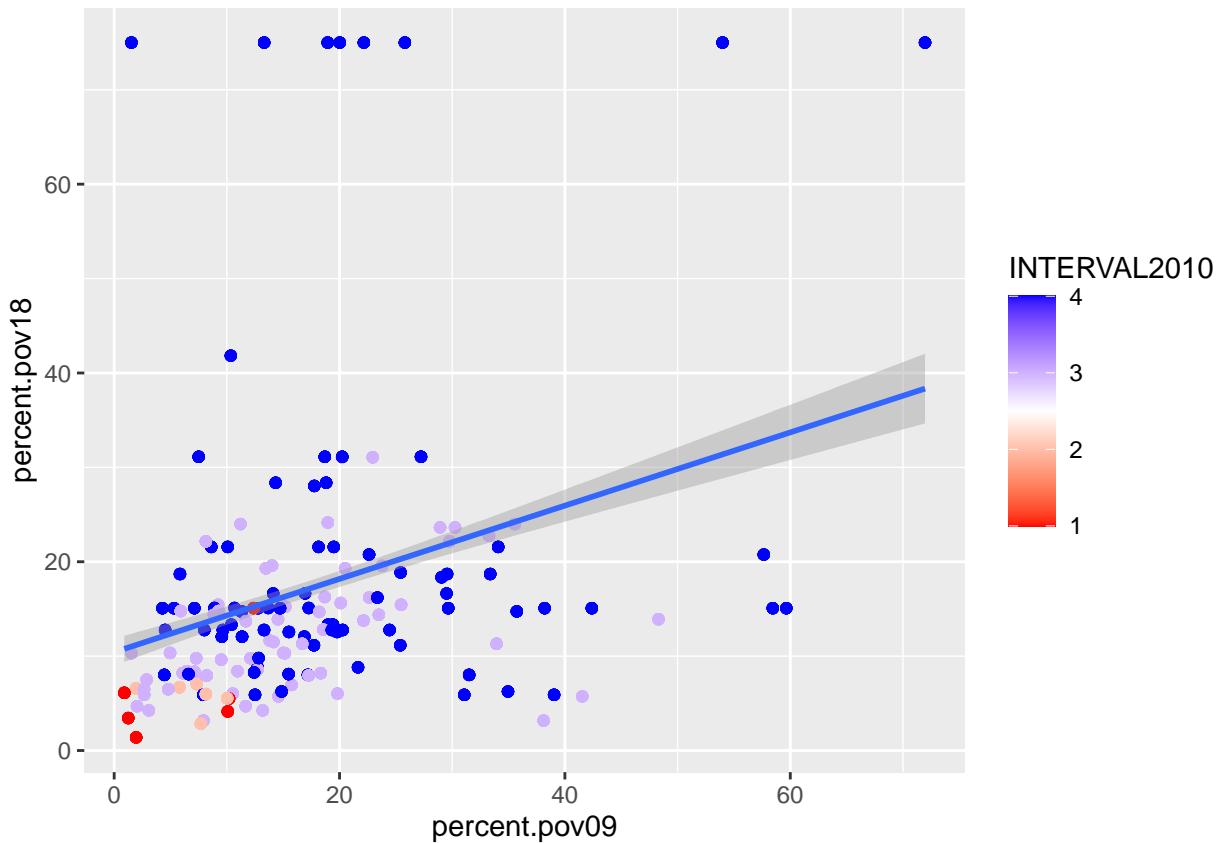
Percent White Change Over Time



Analysis

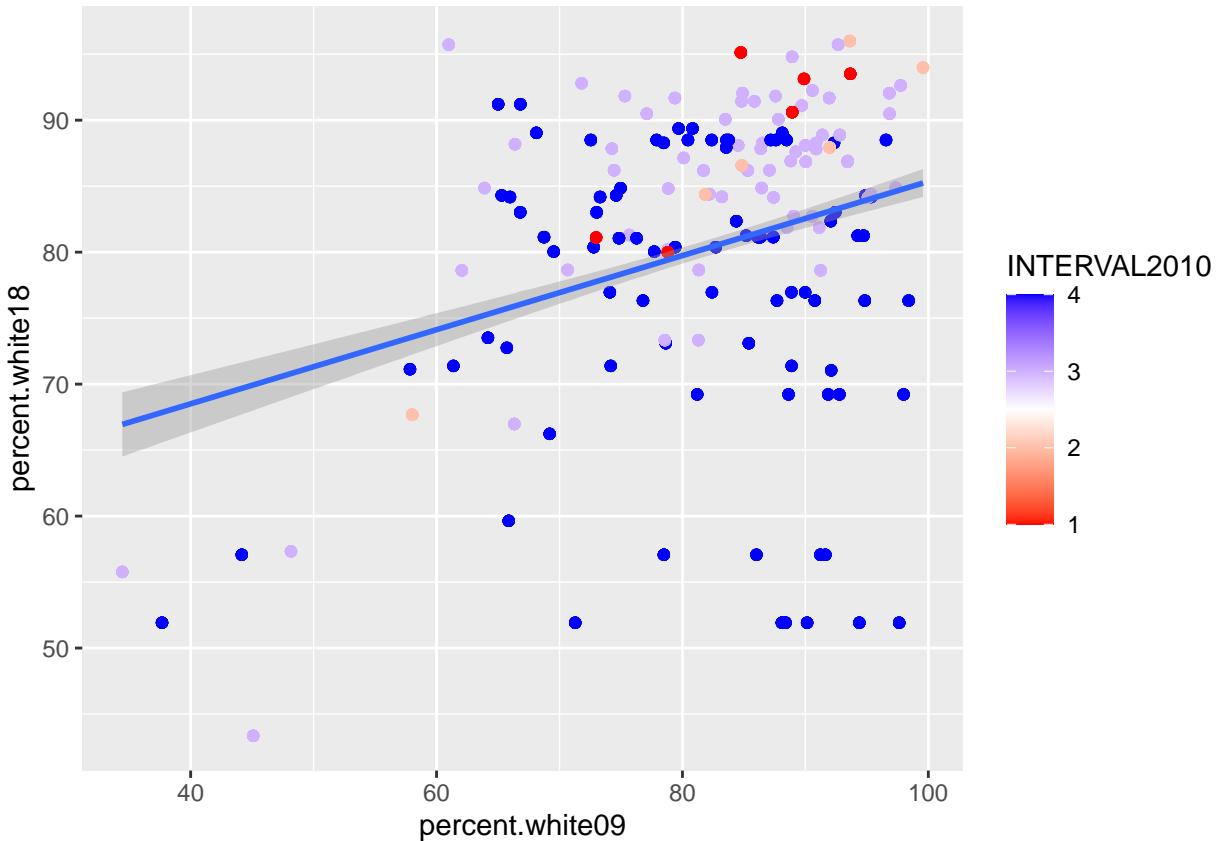
Similar to the previous visualization, this visualization demonstrates the relationship between the percentage of white residents in a tract in 2009 and in 2018. According to this plot, the majority of tracts in Denver experienced an increase in the percentage of white residents from 2009 to 2018. While there are some outliers to this overall trend, it is clear that many tracts experienced an influx of white residents between 2009 and 2018. This change in racial composition reinforces my theory that, after legalization in 2012, Denver experienced rapid gentrification in areas that were formerly impoverished and more diverse due to the demand for legalized marijuana and the construction of dispensaries in these areas.

Redlining Predicting Change Over Time



Analysis

This visualization contains the same data shown in the percent poverty over time map. However, the points in this map now coincide with the redlining score of that tract. All of the tracts with better redlining scores, with "1" indicating an "A" in the redlining category, remain low poverty areas in 2009 and 2018, and many experienced a decrease in poverty between these two time points. The tracts that were previously labeled in the "C" and "D" categories, labeled 3 and 4 on this graph, all contained higher poverty rates in 2009 and in 2018 than those in better redlining categories. This demonstrates that tracts with lower redlining scores are likely to contain more residents living in poverty in 2009 and 2018 due to the implications of redlining on access to resources and ability to mobilize. Between 2009 and 2018, many of these tracts experienced a decrease in percentage of residents living in poverty, shown by the tracts below the trend line. These tracts show the effects of gentrification on poverty in areas that previously had high concentrated disadvantage, as the gentrification that occurred in the 2010s in Denver likely caused this decrease. As previously explained, a key contributor to this gentrification is the legalization of marijuana in 2012, and this is emphasized by the correlation between tract's with high numbers of drug crimes and lower percent poverty and percent white after legalization, which is demonstrated in the next section.

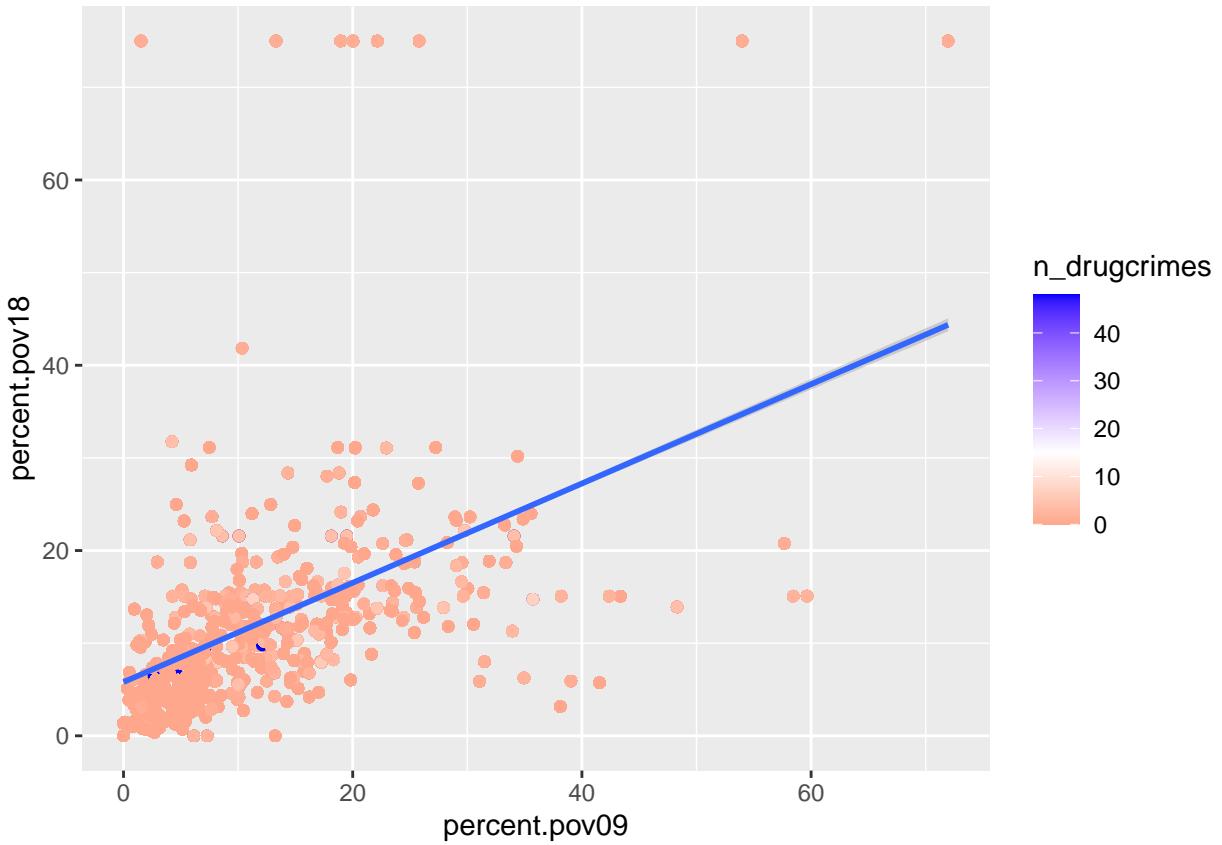


Analysis

This plot contains the same data from the percent white change over time plot. However, the points in this plot now indicate the redlining score for that tract, on a scale from 1 to 5, 1 being the best or “A” category. As seen on this plot, all of the tracts with better redlining scores contained a population that was more than 80% white in both 2009 and 2018. All of these tracts either remained at the same level or experienced an increase in white residents from 2009 to 2018, demonstrating that the tracts with better scores continue to attract white residents due to the implications of historical redlining. The majority of tracts containing lower redlining scores had fewer white residents in 2009 than the tracts with better scores. This demonstrates that redlined tracts still contained more BIPOC in 2009 than tracts that were not redlined, meaning the populations in these tracts remained full of minorities due to the lasting consequences of categorizing these tracts in this way. After the legalization of marijuana in 2012, many of these tracts experienced and continue to experience gentrification, which caused the majority of them to have an increase in white residents between 2009 and 2018. Some of these tracts saw the opposite effect, and this could be due to missing data in 2009, the overall growth of Denver between these areas, or the movement of minority groups out of gentrified areas and into more affordable ones after legalization. Nonetheless, this plot demonstrates that gentrification in the 2010s led to areas with low historical redlining scores to experience an increase in white residents. Similar to the previous plot, this phenomenon can be explained by the growing demand for marijuana in Denver, and this is further analysed below.

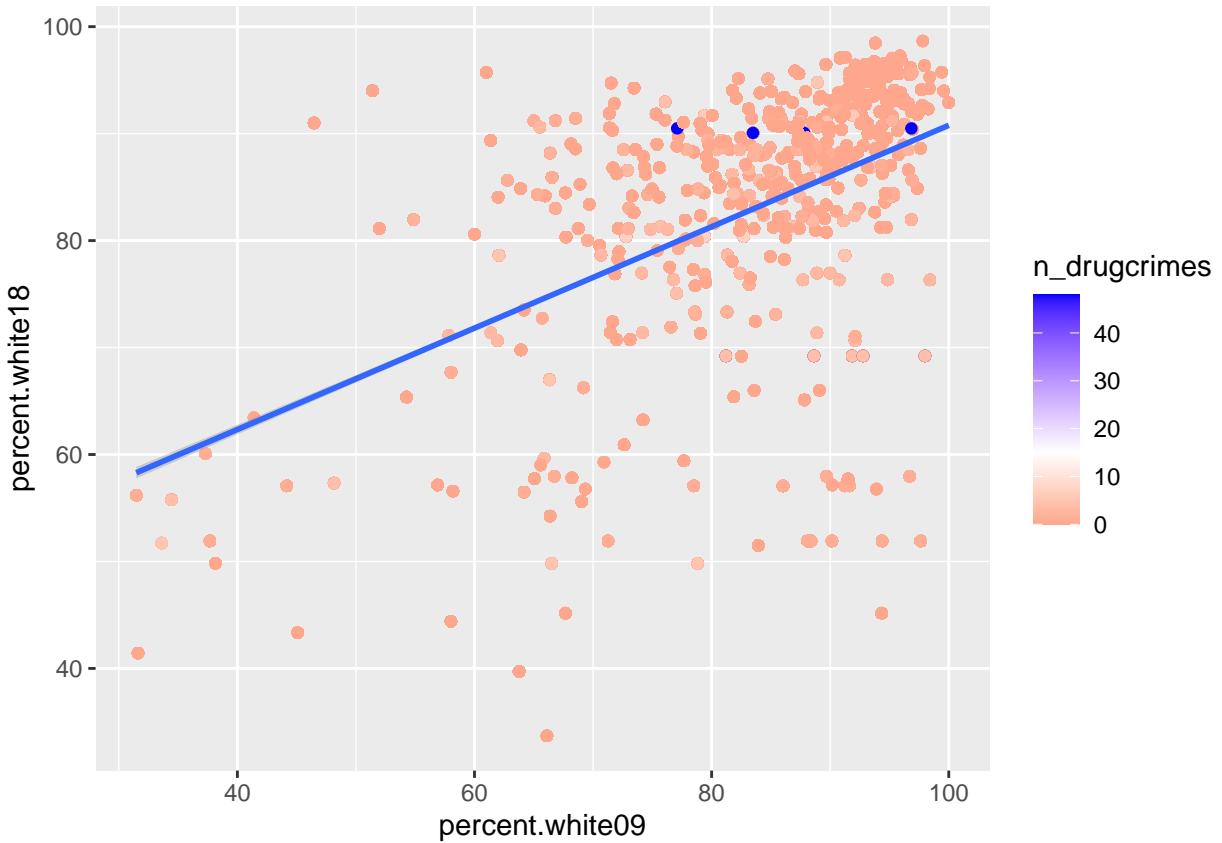
Drug Crimes Change Over Time

Now I will plot models of the change over time for both percent white and percent poverty for each tract. In the plot, I will demonstrate that the tracts with concentrated drug crimes all gentrified between 2009 and 2018, as they all had a decrease in percentage of residents living in poverty and an increase in percentage of white residents.



Analysis

This plot demonstrates the relationship between percent poverty in 2009 and 2018, as demonstrated in similar plots above. However, this plot includes the number of marijuana-related drug crimes in each tract through the color scale of the plot. As seen by the dark purple points on this plot, all of the tracts with high concentrations of drug crimes experienced a decrease in percent poverty from 2009 to 2018. All of these points fall below the trend line and have less poverty in 2018 than in 2009, meaning they likely experienced gentrification between these two points. The points of this plot provide a visual explanation of the theory I began demonstrating with the population maps and regression models in previous sections, as it shows that tracts that previously contained high marijuana-related crimes were gentrified after legalization, leading to less poverty in these areas in 2018.



Analysis

Similar to the above plot, this visualization shows the relationship between percent white residents for 2009 and 2018. Much like the plots in previous sections, this plot shows that the majority of tracts experienced an increase in white residents between these two time points, but, unlike those graphs, it emphasizes the change for tracts with high concentrations of marijuana-related drug crimes. The dark purple points in this plot indicate tracts with high concentrations of marijuana-related crimes. All of these tracts fall above the trend line in this plot and demonstrate an increase in percent white from 2009 to 2018. This increase, along with the sociological theory and other data analysis done in this report, suggests that these tracts experienced gentrification between 2009 and 2018, a large portion of which can be attributed to the legalization of marijuana. We can draw this conclusion because the tracts with more marijuana-related crimes were gentrified over those without these drug crimes, meaning that the demand for marijuana in these areas created an economic opportunity after legalization, and many young, wealthy residents moved into these areas because of it. Whatever the reasoning may be, this plot clearly demonstrates that these tracts experienced a growth in their white populations after legalization.

VII. Summary of takeaways and questions for future research

As a reminder, the key questions I focused on while writing this report were: In what ways did historical redlining shape concentrated poverty and racial residential segregation in Denver in 2009/2010? Were these redlined areas predictive of where marijuana drug arrests were concentrated before legalization? And finally, how do marijuana-related drug arrests in the past predict gentrification in Denver today? After researching and analyzing possible answers to these key questions, I have made several discoveries worth noting.

First, I established that historical redlining scores indicate which tracts will have concentrated poverty and racial residential segregation in 2009. Tracts that were categorized in the “at-risk” or “D” category during the process of historical redlining in the 1930s contained a higher percentage of residents living in poverty and a

lower percentage of white residents than those who received better redlining scores. This phenomenon was demonstrated in maps, regression models, and other visualizations throughout this report. The correlation between these variables was statistically significant and precise, except for with percent poverty in 2018, which could be attributed to the exponential growth of Denver in the 2010s or more census tracts existing in 2018 than in 2009 or the 20th century. Redlining scores also predicted where high concentrations of marijuana-related drug crimes are throughout Denver, as the tracts with lower redlining scores contained more of these crimes. This was demonstrated by regression models and maps in this report, and the coefficient of this relationship was positive and statistically significant, meaning there is a correlation between these two variables. The correlations demonstrated for all of these findings were small, but they were statistically significant and backed by the visual explanations of the same relationships, which indicates that the correlation between historic redlining scores and future poverty percentages, percentage of white residents, and number of marijuana-related drug crimes cannot be ignored or dismissed.

Second, I found that areas with high concentrations of marijuana-related crimes experienced gentrification after the legalization of marijuana in 2012. All tracts with many marijuana-related crimes saw an increase in percent white and a decrease in percent poverty between 2009 and 2018, indicating that the changes in policy and investment into different neighborhoods in Denver led to more wealthy, white residents entering the city. According to the regression models run in this report, the correlation between the number of marijuana-related drug crimes and percent poverty in 2009 and 2018, although it was small, was statistically significant. In these models, as the number of drug crimes in 2010 increased in an area, the percent of residents living in poverty also increased in both 2009 and 2018, but the coefficient for 2018 was less than 2009, meaning these crimes have less of an impact on percent poverty after legalization. This means the number of drug crimes' impact on the percent poverty in a given tract cannot be treated as unimportant or inconsequential. The visualizations and area maps of this relationship reinforce that this correlation is present and important, as these areas with high drug crimes were formerly clusters of poverty and now are some of the wealthiest tracts in downtown Denver.

While I have hypothesized about the major components behind the gentrification in Denver after 2009/2010, there are several driving forces that could be behind this change. The first is that the implementation of dispensaries caused a new demographic to flood into formerly impoverished and high-crime areas, and this is the component I have focused on for the majority of this report. Because the effects of legalization have only been observed in the past ten years, it is difficult to quantify just how impactful this piece of legislation was on the trajectory of Denver, especially in terms of gentrification. However, there have been a few studies that have examined this effect in Denver, and they have found that marijuana dispensaries have indeed caused a growth in the economic market that directly impacts housing cost (Cheng). This rise in housing cost due to the location of dispensaries results in gentrification because new, wealthier residents can afford the rising rent and housing costs, which drives the former residents out due to their inability to keep up with this cost. My analysis pointed me to this cause because of the decrease in percentage of residents living in poverty and increase in percentage of white residents in areas that had high concentrations of marijuana-related drug crimes. Because of this, the theme of marijuana proved significant to the changes in Denver throughout the 2010s, and it is reasonable to assume that the initial demand for the marijuana market began in the tracts with a history of users. In future research on this topic, I hope to include points and models that include where the active marijuana licenses and businesses are to definitively determine if there are clusters of these places where high concentrations of marijuana-related crimes were in 2009. I attempted to use this data in this report, but it was not in a state that would easily join with the data I was already using in my models. Due to the time constraint of this report and my level of comfortability with R Studio, I was unable to add this section.

Other possible causes for the gentrification in Denver that were not discussed in the data analysis portion of this report could be the implementation of different transportation mechanisms in different neighborhoods that could cause tracts to gentrify (Bardaka). Another could be the concept of "green gentrification", a process whereby low-income residents are displaced or excluded from areas with new green amenities, common in areas with an emphasis on environmental conservation like Denver (Russell). Both of these phenomena cause gentrification elsewhere, and likely contribute to this problem in Denver as well. However, the different level of contribution of these variables compared to gentrification due to marijuana dispensaries is unknown,

and this would be another variable I would like to analyse in the future when given more time and with more experience.

Overall, Denver appears to contain many different stories as to why the city has changed so dramatically over the last decade. Redlining scores, percentage of residents living in poverty, and the number of marijuana-related drug crimes appear to be central to all of these explanations due to the concentration of tracts with high poverty rates in Denver's inner-city that also contain high numbers of these drug crimes. The marijuana industry is also a focal piece to mention, as this change in legislation in Colorado altered the state, and therefore its capital city, Denver, significantly in the last ten years. Because all of the areas that previously contained marijuana-related crimes and activity experienced some level of gentrification after legalization, it is impossible to ignore the small conclusions found in this report concerning this relationship.

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