The Effects of Colorado's Recreational Cannabis Industry on Colorado Gambling: An Empirical Approach

An Honors Thesis for the Department of Economics

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Introduction:

Although cannabis use and possession within the United States has been federally illegal since the passing of the Controlled Substance Act of 1970, this has not prevented individual states from creating their own laws in regards to the substance. While 33 states and the District of Columbia have legalized the medical use of cannabis, ten states have legalized both medical and recreational use. The mass regulation and creation of the cannabis industry has come quickly and, as such, there needs to be more research focused on understanding what the effects of this plant are on overall industry. Of particular interest to me is the effects the emerging cannabis industry is having on consumers' feel good expenditure because, as recreational cannabis is certainly a feel good expenditure like alcohol, tobacco, and gambling, it may have a unique relationship with these other pastimes. Given the ample research on the substance's effects on alcohol consumption, and also the relationship between alcohol consumption and gambling, this research focuses on the new cannabis industry's effects on gambling, an area that has yet to be studied using empirical sales data. Specifically, due to the availability of information in Colorado, I will be analyzing the relationship between recreational cannabis sales and available gambling metrics in Colorado. It is important to note outright that studies analyzing the relationships between addictive habits like alcohol and gambling and cannabis must do a good job at controlling the sample – for the ultimate goal is determining if an individual will increase or decrease consumption of something after treatment. As such, the majority of research implements either a survey or differences in differences approach and is more often psychological than economic by nature. Because the recreational cannabis industry in Colorado is so new and because it was the first in the United States, the results I have generated cannot infer causality on the individual level. I set out with the hypothesis that an increase in cannabis use would decrease gambling expenditure because of the research discussed in the literature review. But because of factors outside of my control, namely the black market and visitors, I cannot isolate a sample to understand how one person's use of cannabis

would impact his or her gambling habits. I can, however, prove that the legal cannabis industry, for the time being, has greatly increased gambling revenue in Colorado and in specific gambling establishments.

I will begin with a brief literature review and a description of my data and sources, and will follow this with a map of county cannabis retails sales. I will then go into the differences in means to describe the entire state's gambling industry and the respective industries of the individual cities. From here I will go into the regressions, which are broken down into macro and micro levels. On the macro level I want to understand how the cannabis industry in Colorado has changed the entire state's gambling industry. On the micro level I want to understand how the cannabis industry has changed each specific gambling location, whether it's Black Hawk, Central City, or Cripple Creek. For both macro and micro analyses I will conduct differences in means, multivariate regressions, and fixed effects panel regressions of gambling metrics on cannabis retail sales to demonstrate that the increases we see in gambling metrics are certainly a result of the legal cannabis industry.

Literature Review:

No economic paper addresses the research question I am here; however, there are multiple papers I have drawn on for formulating my hypothesis. I have divided the literature into three parts: research about the relationship between alcohol and cannabis use, research about the relationship between gambling and alcohol use, and research about the relationship between gambling and cannabis use.

The research surrounding the substitution or complementarity of cannabis and alcohol had been mixed up until a breakthrough economic paper published in 2017 with the fitting title "Helping Settle the Marijuana and Alcohol Debate: Evidence from Scanner Data" by Baggio, Chong, and Kwon found that cannabis and alcohol are substitutes. Using a differences in differences approach to evaluate the causal effects of medical marijuana legalization on alcohol sales, the study

analyzed point-of-sale, county specific data on alcohol expenditure collected by Nielsen before and after US states legalized medical marijuana and found that there was a 12.4% average reduction in county alcohol sales post legalization. Before this research was published, Subbaraman (2016) conducted an in-depth literature review of all the papers analyzing the relation between cannabis and alcohol. Of the 39 papers she reviewed, around 40% of them found evidence in support of a substitution effect between marijuana and alcohol; around 24% of them found evidence is support of a complementary relationship; and around 34% of them found no evidence of either a substitution or a complementary effect between marijuana and alcohol.

There is much evidence that gambling expenditure and alcohol consumption are inextricably linked. Individuals who consume alcohol excessively are more likely to gamble than individuals who do not. Walker et al., (2010) found that individuals who partake in casino gambling have a 20% greater probability of binge drinking than individuals who do not partake. Feigelman et al., (1995) found that alcohol use in the past month and historical issues with alcohol consumption were significantly correlated to gambling problems. Ladouceur et al., (1999) also found pathological gambling to be associated with alcohol use. Studies involving clinical populations have shown both that rates of pathological gambling are higher amongst individuals with alcohol use disorders (Daghestani et al., 1996; Lesieur and Heineman, 1988) and that rates of alcohol use disorders are higher amongst pathological gamblers (Ramirez et al., 1983). Reviewing the literature at the time, Stewart and Kushner, (2005) developed three possible ways that excessive drinking and heavy gambling might be related: gambling disorders could cause or increase alcohol consumption, heavy drinking could cause or increase problem gambling, or there could be no causal relationship between the two but rather a third variable causing both gambling and drinking problems like an underlying dysregulation of the dopamine system. The research studies demonstrate a clear positive relationship between alcohol consumption and gambling expenditure, but so too do the habits of most casinos. It is no wonder that casinos around the world often push

free alcohol to their customers, have constant servers and many bars available within a quick stroll from the gambling tables and slots - individuals are simply more likely to participate in higher stakes and spend more money if they are under the influence of alcohol. Casinos know this and have been acting on it for a very long time.

There are a few studies that analyze cannabis use and gambling. One study by Cronce et al., (2016) surveyed more than 1,800 west coast university students with the goal of seeing how cannabis use relates to frequency, severity, and amount lost during gambling compared to their alcohol consumption. The study concluded that cannabis use alone may indicate similar risks to negative gambling outcomes as alcohol use alone and that cannabis use alone also had similar risks of negative gambling results as use of both cannabis and alcohol. Another study found that of 61 pathological gamblers who were also seeking treatment for substance abuse, more of the participants reported problematic cannabis use than did report problematic alcohol consumption (Toneatto and Brennan, 2002). The psychological survey studies seeking to understand how cannabis use affects gambling lack the ability to infer causality just as the alcohol and gambling studies do.

Cannabis use, if there is indeed a substitution effect between cannabis and alcohol and if there is a positive relationship between alcohol consumption and gambling, might have a negative impact on an individual's gambling expenditure if that individual decreases alcohol consumption in favor of cannabis use. If Coloradoans are consuming less alcohol than they did prior to legalization, and if they are consuming more cannabis instead, perhaps we would see a decrease in gambling expenditure. However, increasing cannabis use may also be related to an individual's gambling expenditure and problems with gambling, as a few of the studies mentioned previously observed. Although I don't have information on gamblers who decrease their consumption of alcohol in favor of cannabis, I do have detailed monthly information on cannabis sales and gambling metrics. This being the case, the research I conduct is not into the intrinsic relationship, substitution or

complementary, between cannabis use and gambling amount. Rather, it is a case study on how the Colorado gambling industry has changed, if at all, from the legalization of recreational cannabis. This is important because we are entering unchartered territory with the legalization of cannabis around the United States, and states should want to have a good understanding of how industries may change or be impacted by the legalization of it, especially industries like gambling that provide tens of millions of dollars in tax revenue to each state. Indeed, as cannabis becomes normalized, we most likely will see a reduction in the affects that cannabis legalization has on tourist reliant industries.

Data review:

The data collected for my research was supplied by the Colorado Department of Revenue. I have obtained monthly recreational sales data for every county that has at least three taxpayers and where none of the taxpayers represents more than 80% of tax revenue in a given month since Colorado began legal recreational sales in January 2014 until November 2018. Recreational cannabis sales is synonymous with retail cannabis sales and is calculated from the net sales, gross minus wholesale, of all items that contain consumable marijuana. I have collected the monthly gaming industry statistics from August 2009[1] until November 2018 for the three cities that permit legal, taxable gambling in Colorado: Black Hawk, Central City, and Cripple Creek. There are two different broad methods of gambling - machine games and table games. Machine games consist of low denomination slot machines ranging from 1¢ to $5, multi denomination slot machines, and high denomination slot machines. Because each city differs widely in its machine gaming, I have used solely the statistics on total aggregate monthly slot machines for the state and each city in this analysis. Table games consist of blackjack, craps, roulette, and poker. For every method of

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[1] Although the financial year for the gambling industry in Colorado begins in July, the state implemented higher limits in July of 2009, rendering that July and prior months difficult to work with.

gambling I have: the number of machines or tables dedicated to that game, the total amount

wagered or dropped, and the adjusted gross proceeds (AGP, which is found by subtracting total

money paid out from the total amount dropped or wagered). Amount wagered differs between

table games and slot machines by method of calculation. A slot machine is able to record the total

amount of money put into the machine, and therefore wagered, while table games can only

calculate how much money has been exchanged for chips and dropped at the dealer's feet in a

special container, hence the term drop. When people play table games they can obtain chips

different ways, either by exchanging cash directly at the table at which they are playing or by

exchanging with the cashier at the entrance to the casino, and this money is not always wagered.

Further, once people have chips, they can move to different tables and different games, so there is

ambiguity as to what the actual waged amount for table games is. For simplicity, we can interpret

"drop" as the amount in play for table games and as the amount wagered for slot machines. The

proceeds a casino makes from table games are also obtained differently than the proceeds

generated from slot machines. While casinos employ many different means through which to profit

from table game players, like commission from winning pots in the case of poker, slot machines are

obviously much simpler. In order to weight my panel regressions according to the population of

each county, I use the US census data from 2010.

Table 1: Summary statistics of cannabis retail sales[2]

Cannabis Retail Sales	Obs	Mean	Std. Dev.	Min	Max
County	1393	$ 2,669,278	$ 5,101,974	$ 95,793	$ 35,343,772
State	59	$ 66,806,252	$ 28,779,980	$ 14,022,213	$ 112,998,245

[2] Because county level observations, averaging 43.5 per county with 32 counties, differ from state level observations, aggregate county means are greater than the state's mean.

County Cannabis Retail Sales Map:
County specific mean cannabis retail sales as percent of total with gambling locations
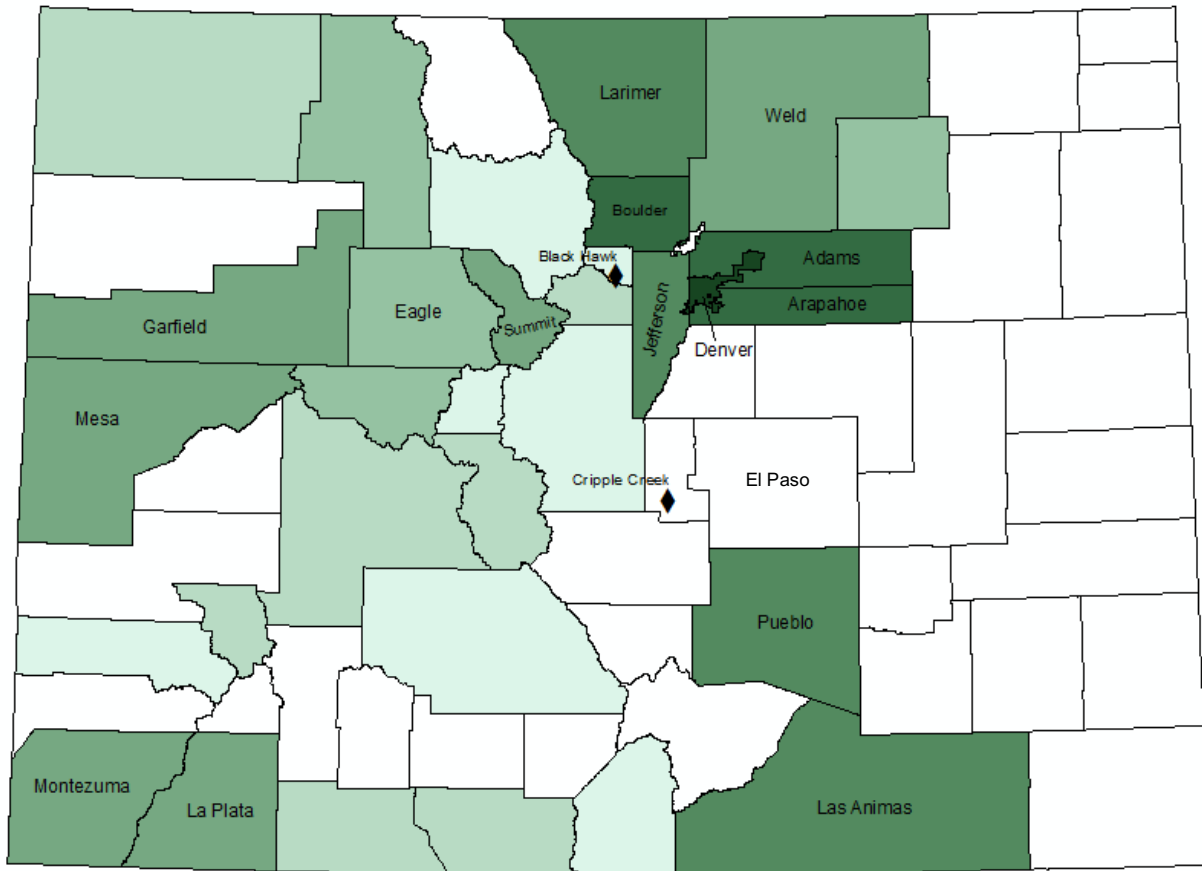
Note: White counties have no reported cannabis retail sales because of less than three taxpayers or one taxpayer accounting for more than 80% of tax collected. ♦ indicates a gambling location and Black Hawk and Central City use the same ♦. Counties with +$1 million of recreational cannabis sales are named, not including El Paso.

Cannabis Retail Sales as Percent of Total

☐	0.2% - 0.5%	☐	3.1% - 6%
☐	0.51% - 1%	☐	6.1% - 12%
☐	1.1% - 1.5%	☐	12.1% - 34%
☐	1.51% - 3%		
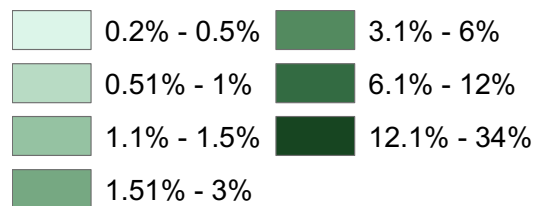
This map, created with ArcGIS, illustrates how each county's mean monthly recreational cannabis sales relates to each other's. Rather than being a percent of statewide mean sales, the counties are shaded by percent of aggregate county mean monthly cannabis sales. It shows how there is a significant border affect caused by visitors traveling across state boundaries (New Mexico to the south, Utah to the west, Wyoming to the North) to purchase legal cannabis, with the most

legal border state being New Mexico allowing medical. Las Animas has mean monthly cannabis

sales of around $2.5 million with a population of roughly 15,000. And Montezuma has mean

monthly cannabis sales of around $2 million with a population of about 25,000. It is evident that

there's a large concentration of sales around Denver, which can be attributed to the population of

counties in the neighborhood, high amounts of tourists, and cheaper products (Orens et al., 2018).

The map is also a useful way to see the proximity of each gambling city to each county with

cannabis retail sales, for reference to Appendix D.

Differences in Means:

To begin the analysis, I would like to see how gambling metrics differ in their means before

and after cannabis legalization, and whether or not these differences are significant. I have done

this by implementing a t test for each gambling metric, using Satterthwaite's degrees of freedom to

account for unequal variances in the before and after groups. Before cannabis legalization I have 53

months of observations, from August 2009 to December 2013. After legalization I have 59 months

of observations, from January 2014 to November 2018. The p-values used to determine significance

come from the alternative hypotheses that the difference in means is either greater than or less

than zero, the null hypothesis being that the difference in means is equal to zero. If the p-value of a t

test is less than or equal to .05, I reject the null in favor of the respective alternative hypothesis and

assign an asterisk according to the p-value legend. Difference in means is calculated by subtracting

the before legalization group's mean from the after legalization group's means, as this better

represents the change from the before period to the after period.

The problem with differences in means is that one cannot infer causality from it. If there is a

time trend before an event, in this case the legalization of recreational cannabis in Colorado, and

this trend continues, there will obviously be a significant change in the means within the two

periods. Another problem with the t test for differences in means is that if there is a significant

change in the slope of the regression line in the opposite direction, for example a 0.5 slope before becomes -0.5 after the event, then the means within the two groups can easily be very similar and the t test would then state that there is no significant difference between them – which is rightfully so, as it is only testing the means of two groups. Because of these problems I have included a few graphs of gambling metrics to illustrate how expenditure changed. For detailed graphs of how expenditure at every table game and total slots, and total AGP change over time for each city and the entire state, refer to Appendix B.

<u>T test 1: Colorado Gambling Metrics</u>

Craps Drop	Mean		Std. Dev.	***
Before 01/2014	$	5,825,566	$	494,718
After 01/2014	$	6,502,539	$	572,298
Difference	$	676,973		
DF: 110				

Craps AGP	Mean		Std. Dev.	***
Before 01/2014	$	1,208,609	$	111,096
After 01/2014	$	1,406,950	$	168,659
Difference	$	198,341		
DF: 101				

Poker Drop	Mean		Std. Dev.	***
Before 01/2014	$	3,503,443	$	340,727
After 01/2014	$	4,367,765	$	475,356
Difference	$	864,322		
DF: 105				

Poker AGP	Mean		Std. Dev.	***
Before 01/2014	$	866,265	$	102,145
After 01/2014	$	1,168,886	$	161,346
Difference	$	302,621		
DF: 99				

Blackjack Drop	Mean		Std. Dev.	***
Before 01/2014	$	14,715,578	$	843,551
After 01/2014	$	16,509,923	$	1,314,308
Difference	$	1,794,345		
DF: 100				

Blackjack AGP	Mean		Std. Dev.	***
Before 01/2014	$	2,427,909	$	244,982
After 01/2014	$	3,433,856	$	468,955
Difference	$	1,005,947		
DF: 89				

Roulette Drop	Mean		Std. Dev.	***
Before 01/2014	$	2,427,075	$	249,346
After 01/2014	$	3,708,663	$	614,791
Difference	$	1,281,588		
DF: 78				

Roulette AGP	Mean		Std. Dev.	***
Before 01/2014	$	590,068	$	66,737
After 01/2014	$	938,340	$	186,865
Difference	$	348,272		
DF: 74				

Slots Drop	Mean		Std. Dev.	
Before 01/2014	$	811,428,736	$	59,500,000
After 01/2014	$	805,749,568	$	59,800,000
Difference	$	(5,679,168)		
DF: 109				

Slots AGP	Mean		Std. Dev.	**
Before 01/2014	$	56,446,192	$	3,815,641
After 01/2014	$	58,648,384	$	4,808,125
Difference	$	2,202,192		
DF: 108				

*p<=.05; **p<=.01; ***p<=.001

Total AGP	Mean		Std. Dev.	***
Before 01/2014	$	62,946,592	$	4,101,644
After 01/2014	$	66,884,740	$	5,469,772
Difference	$	3,938,148		
DF: 107				

<u>Change in Monthly Mean Gambling Metrics Before and After Legalization:</u>

| State	Craps	Poker	Blackjack	Roulette	Total Coins In	Total AGP
% Change Drop	11.6%	24.7%	12.2%	52.8%	-0.7%	n/a
% Change AGP	16.4%	34.9%	41.4%	59.0%	3.9%	6.3%

Note the differences in standard deviations in the before groups versus the after groups. This can be explained by the increased number of visitors entering Colorado – the Colorado Tourism Office reports an almost 30% increase in annual tourists and a 14% increase in their annual expenditure from 2012 to 2015, with a record 77.7 million visitors spending $16.7 billion (Belvins, 2016). Further, Denver County, which is responsible for roughly 13% of the state's population, accounted for 33.1% of aggregate mean county cannabis retail sales[3]. I don't know exactly what portion of these sales is from visitors, or the exact increase in visitors due to cannabis legalization (some people would have visited anyway while others wouldn't have), but there are certainly more people visiting Colorado than before, presumably because of the legalization of cannabis; no other major impetus is apparent.

The only metric that does not have a statistically significant different mean is Slots Drop. Roulette Drop and AGP changed the most, with a 52.8% and 59% change respectively. The biggest changes in drop metrics following roulette are Poker at 24.7%, Blackjack at 12.2%, Craps at 11.6%, and Slots at -0.7%. The most prominent difference in the changes of AGP and Drop can be found in Blackjack – while the monthly mean of Blackjack Drop increased 12.2% between the two periods, the Blackjack AGP monthly mean increased by 41.4%, a 29.2% difference. It makes sense that the change in Adjusted Gross Proceeds is greater than the Drop amount, as casinos are implementing their own strategies to gain more profit over time. But an almost 30% difference can only be explained by rapid changes in casino strategy, by legitimate changes in the betting habits of players, or by changes in the population of gamblers, which can be induced by new players coming to play. Other than recreational cannabis potentially impacting people's decision making and increasing the

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[3] Denver County accounted for 35.3% of statewide mean cannabis sales.

number of available gamblers, the casinos most likely are deploying more 6:5 Blackjack games that have lower limits than 3:2 games. This is the strategy being rolled out in Las Vegas that has professional players annoyed (Renzey, 2017). In 6:5 games, the casino pays out 6 dollars for every 5 dollars bet to a winning hand, compared to 3 dollars for a 2 dollar bet in 3:2 games. 6:5 games often use one deck to make them more appealing, as this makes predicting the next card easier, and allow lower limit bets (less than $25). But 6:5 games actually increases the house edge to almost 2%, compared to .5% with 3:2 if a player plays perfect basic strategy (Renzey, 2017). I do not have detailed information on the types of tables there are in Colorado.
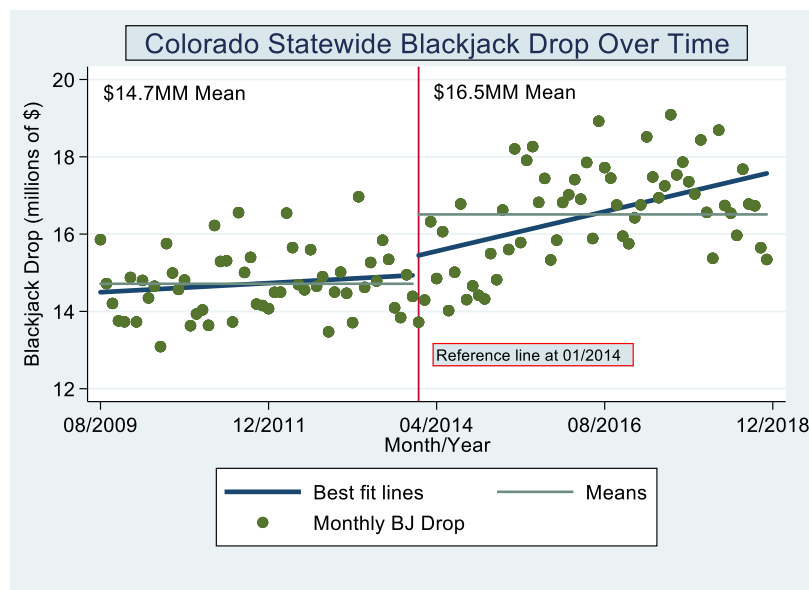
The monthly mean of Blackjack Drop in the entire state increased from $14.7 million in period one to $16.5 million in period two, a 12.2% increase. The t test conducted on these two periods is significant at the .001 level.

Colorado Statewide Blackjack AGP Over Time
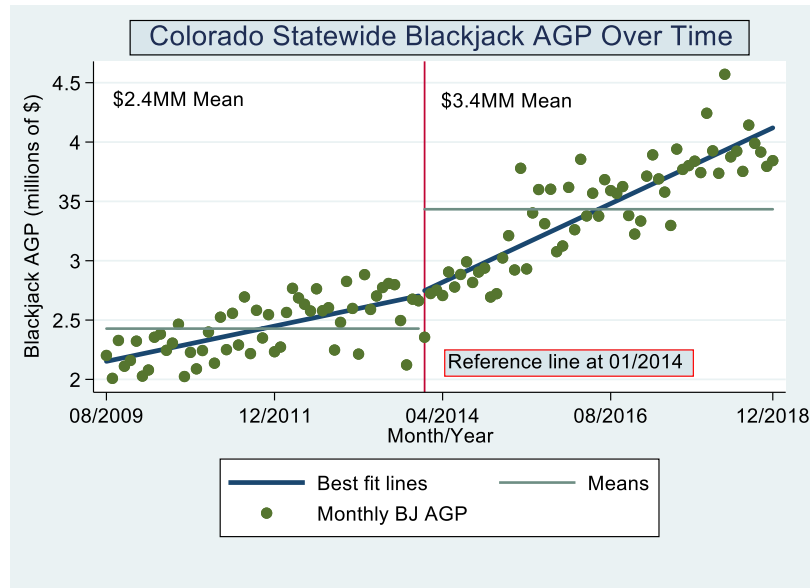
The monthly mean of Blackjack AGP in the entire state increased from $2.4 million in period

one to $3.4 million in period two, a 41.4% increase. This significant jump is offset partially by the

upward trend evident before legalization of cannabis occurred. Dividing the Adjusted Gross

Proceeds statistic by the Drop, we obtain the hold percentage, which is the percent of revenue

obtained from Drop amount. Before legalization occurred, the mean hold percentage for Blackjack

was 16.5%. Afterwards, the mean hold percentage was 20.8% – meaning that for every $100

dropped at the Blackjack table in Colorado, a person would lose an extra $4.30.

Colorado Statewide Slot Expenditure Over Time
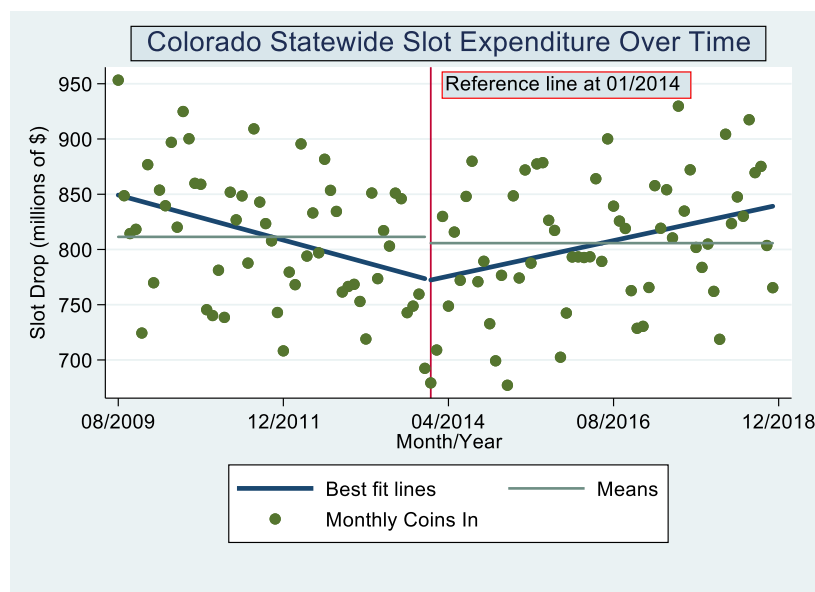
One can see the reason the t test reported the difference in means to be insignificant for slot expenditure – the means are essentially the same in the two groups. However, by looking at the difference in slopes, it becomes somewhat obvious that the legalization of cannabis has had significant effects on slot machine gambling.
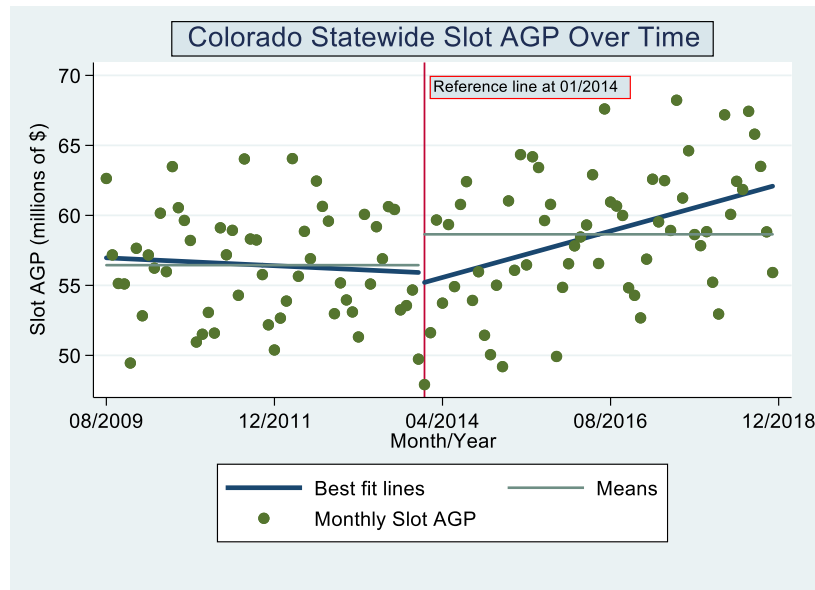
The t test on the monthly mean for statewide Slot AGP verified a significant difference in the means at the .01 level. The difference in slopes is also evident in this graph, which is to be expected. Before cannabis legalization, statewide slot hold percentage averaged 6.96%. After cannabis legalization, this percent increased to 7.28%.

Colorado Statewide Roulette Drop Over Time
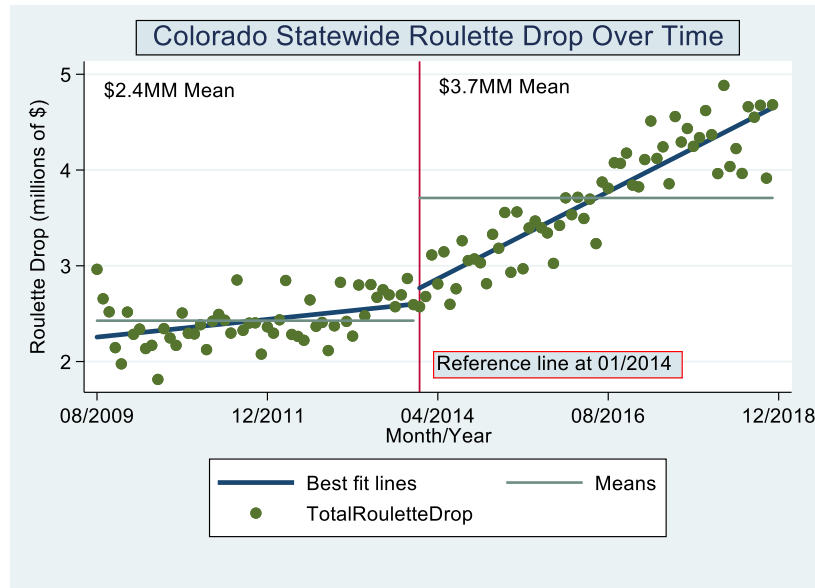
The difference in means for Roulette Drop is significant at the .001 level. Before cannabis legalization, monthly mean Roulette Drop in the state was $2.4 million and this increased to $3.7 million post legalization, an increase of 52.8%. What is especially interesting is that the slopes of the best fit lines in each period are very different from each other.

City specific differences in means:

Going into the results of the t tests for each individual gambling city, it is important to keep an eye on the city's role in influencing the entire state. I have included simple tables, Appendix 1A, and simple graphs, Appendix 2A, to help illustrate that each gambling city is very different from each other in their makeups of statewide gambling metrics.

T test 2: Black Hawk Gambling Metrics

Craps Drop	Mean		Std. Dev.	***
Before 01/2014	$	4,530,911	$ 357,225	
After 01/2014	$	5,363,162	$ 484,503	
Difference	$	832,251		
DF: 106				

Craps AGP	Mean		Std. Dev.	***
Before 01/2014	$	942,456	$ 85,329	
After 01/2014	$	1,153,877	$ 140,395	
Difference	$	211,421		
DF: 97				

Poker Drop	Mean		Std. Dev.	***
Before 01/2014	$	2,817,985	$ 294,408	
After 01/2014	$	3,830,486	$ 459,993	
Difference	$	1,012,502		
DF: 100				

Poker AGP	Mean		Std. Dev.	***
Before 01/2014	$	700,363	$ 98,423	
After 01/2014	$	1,023,187	$ 161,151	
Difference	$	322,824		
DF: 97				

Blackjack Drop	Mean		Std. Dev.	***
Before 01/2014	$	11,689,742	$ 652,869	
After 01/2014	$	13,513,117	$ 1,179,060	
Difference	$	1,823,375		
DF: 92				

Blackjack AGP	Mean		Std. Dev.	***
Before 01/2014	$	1,950,666	$ 192,032	
After 01/2014	$	2,805,799	$ 421,138	
Difference	$	855,133		
DF: 83				

Roulette Drop	Mean		Std. Dev.	***
Before 01/2014	$	2,034,581	$ 214,935	
After 01/2014	$	3,272,357	$ 629,095	
Difference	$	1,237,776		
DF: 73				

Roulette AGP	Mean		Std. Dev.	***
Before 01/2014	$	489,026	$ 57,100	
After 01/2014	$	819,672	$ 188,449	
Difference	$	330,646		
DF: 70				

Slots Drop	Mean		Std. Dev.	
Before 01/2014	$	572,357,760	$ 38,400,000	
After 01/2014	$	576,201,152	$ 40,400,000	
Difference	$	3,843,392		
DF: 110				

Slots AGP	Mean		Std. Dev.	***
Before 01/2014	$	40,923,228	$ 2,502,687	
After 01/2014	$	43,156,688	$ 3,339,531	
Difference	$	2,233,460		
DF: 107				

*p<=.05; **p<=.01; ***p<=.001

Total AGP	Mean		Std. Dev.	***
Before 01/2014	$	46,210,300	$ 2,720,036	
After 01/2014	$	50,135,164	$ 3,911,088	
Difference	$	3,924,864		
DF: 104				

Change in Monthly Mean Gambling Metrics Before and After Legalization

Black Hawk	Craps	Poker	Blackjack	Roulette	Total Coins In	Total AGP
% Change Drop	18.4%	35.9%	15.6%	60.8%	0.7%	n/a
% Change AGP	22.4%	46.1%	43.8%	67.6%	5.5%	8.5%

Black Hawk is the biggest gambling city in Colorado, and because of this, the changes we see at the state level will be primarily due to the changes in Black Hawk. Black Hawk is the biggest gambling city due to its proximity to Denver, Colorado, which boasts the highest tourism rates in the entire state in addition to being the most populous. Because of the similarities between

statewide gambling metrics and Black Hawk specifically, graphs are not needed but can be
observed in Appendix 2B. As a percent of Adjusted Gross Proceeds in the entire state, Black Hawk
made up 73.4% of statewide mean monthly AGP in the period before cannabis legalization and
made up 75% of it post legalization (Appendix 1A), telling us that the share of gross proceeds to
casinos in the state have shifted more towards Black Hawk – which could possibly be explained by
the theory that increased tourism has disproportionately affected Black Hawk's gambling metrics.
In every metric, amount dropped has increased for Black Hawk, and this is in stark comparison to
the other gambling locations.
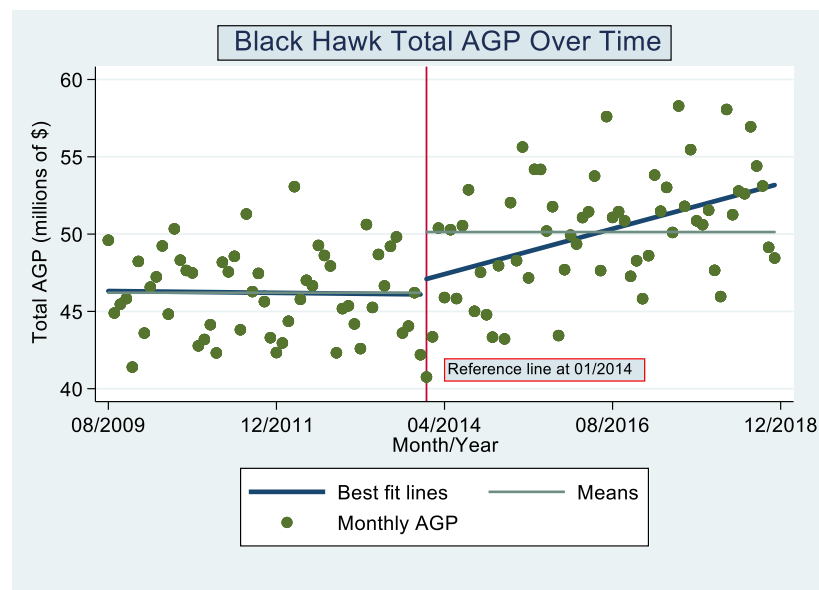
The before legalization period shows a flat slope with little time trend. After legalization
there is a clear increase in the slope of the line and an increase in the Total AGP as time goes on.

T test 3: Central City Gambling Metrics

Craps Drop		Mean		Std. Dev.	***
Before 01/2014	$	537,983	$	66,308	
After 01/2014	$	437,082	$	55,505	
Difference	$	(100,901)			
DF: 102					

Craps AGP		Mean		Std. Dev.	***
Before 01/2014	$	106,327	$	26,354	
After 01/2014	$	86,473	$	27,465	
Difference	$	(19,854)			
DF: 110					

Poker Drop		Mean		Std. Dev.	***
Before 01/2014	$	264,788	$	147,244	
After 01/2014	$	97,503	$	27,093	
Difference	$	(167,285)			
DF: 55					

Poker AGP		Mean		Std. Dev.	***
Before 01/2014	$	57,479	$	29,838	
After 01/2014	$	25,312	$	9,738	
Difference	$	(32,167)			
DF: 62					

Blackjack Drop		Mean		Std. Dev.	
Before 01/2014	$	921,985	$	203,143	
After 01/2014	$	916,982	$	98,845	
Difference	$	(5,003)			
DF: 73					

Blackjack AGP		Mean		Std. Dev.	***
Before 01/2014	$	140,890	$	44,410	
After 01/2014	$	175,808	$	35,415	
Difference	$	34,918			
DF: 99					

Roulette Drop		Mean		Std. Dev.	***
Before 01/2014	$	123,947	$	40,396	
After 01/2014	$	93,846	$	26,652	
Difference	$	(30,101)			
DF: 88					

Roulette AGP		Mean		Std. Dev.	**
Before 01/2014	$	30,212	$	13,939	
After 01/2014	$	24,296	$	6,994	
Difference	$	(5,916)			
DF: 75					

Slots Drop		Mean		Std. Dev.	**
Before 01/2014	$	77,306,624	$	7,228,696	
After 01/2014	$	73,513,968	$	7,470,916	
Difference	$	(3,792,656)			
DF: 109					

Slots AGP		Mean		Std. Dev.	
Before 01/2014	$	5,317,401	$	521,681	
After 01/2014	$	5,475,963	$	650,442	
Difference	$	158,562			
DF: 109					

*p<=.05; **p<=.01; ***p<=.001

Total AGP		Mean		Std. Dev.	
Before 01/2014	$	5,701,411	$	538,927	
After 01/2014	$	5,802,822	$	649,737	

Change in Monthly Mean Gambling Metrics Before and After Legalization

Central City	Craps	Poker	Blackjack	Roulette	Total Coins In	Total AGP
% Change Drop	-18.8%	-63.2%	-0.5%	-24.3%	-4.9%	n/a
% Change AGP	-18.7%	-56.0%	24.8%	-19.6%	3.0%	1.8%

Central City is the smallest gambling city in Colorado, with monthly AGP averaging a little more than 10% of Black Hawk's monthly AGP. It is within two miles of Black Hawk; however, because it is located two miles to the west, rather than to the east, traffic from Denver gets gobbled up by Black Hawk – If one is a tourist or a resident who wants to gamble, there is little point in going further out of the way unless this person wants to evade the crowd. Those who want to evade

the crowd may be slot machine gamblers, as these are solitary games compared to table games that require interaction with other gamblers. It is not surprising then that Central City's share of slot machine drop in the state is the highest of all its gambling metrics, both before and after legalization (9.5% and 9.1%, respectively – Appendix 1A). It is important to note the difference between the changes in drop percentages for Central City and the changes for Black Hawk as they are so close to each other – while the means for every gambling drop metric went up in Black Hawk, the means for every gambling drop metric went down in Central City.
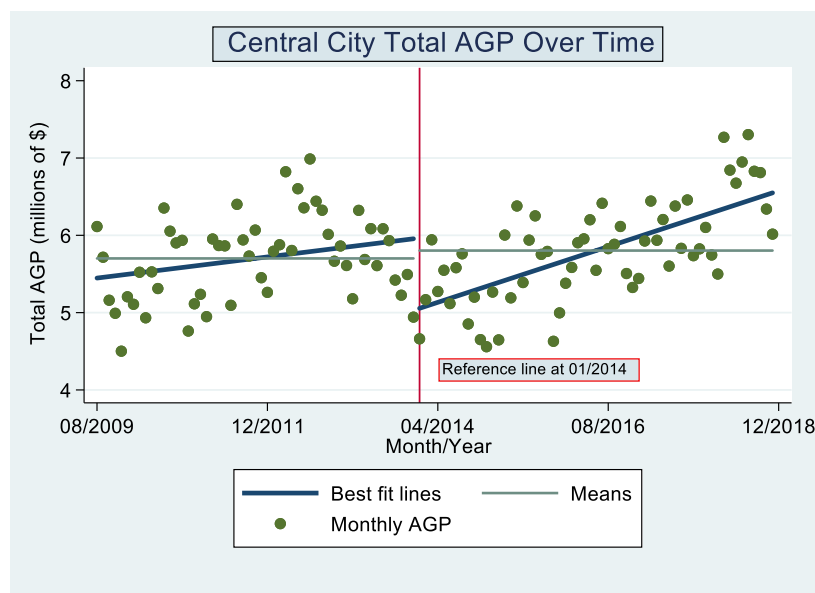
In the before legalization period for Central City, there is clearly a downward trend beginning in the end of 2012, and after legalization this trend seems to be corrected.

T test 4: Cripple Creek Gambling Metrics

Craps Drop	Mean	Std. Dev.	*
Before 01/2014	$ 756,673	$ 129,674	
After 01/2014	$ 702,296	$ 121,592	
Difference	$ (54,377)		
DF: 107			

Craps AGP	Mean	Std. Dev.	
Before 01/2014	$ 159,826	$ 43,047	
After 01/2014	$ 166,600	$ 37,955	
Difference	$ 6,774		
DF: 104			

Poker Drop	Mean	Std. Dev.	
Before 01/2014	$ 420,670	$ 84,706	
After 01/2014	$ 439,775	$ 53,073	
Difference	$ 19,105		
DF: 86			

Poker AGP	Mean	Std. Dev.	**
Before 01/2014	$ 108,423	$ 22,220	
After 01/2014	$ 120,387	$ 23,007	
Difference	$ 11,964		
DF: 109			

Blackjack Drop	Mean	Std. Dev.	
Before 01/2014	$ 2,103,851	$ 242,520	
After 01/2014	$ 2,079,825	$ 212,999	
Difference	$ (24,026)		
DF: 104			

Blackjack AGP	Mean	Std. Dev.	***
Before 01/2014	$ 336,353	$ 51,003	
After 01/2014	$ 452,249	$ 65,615	
Difference	$ 115,896		
DF: 108			

Roulette Drop	Mean	Std. Dev.	***
Before 01/2014	$ 268,547	$ 51,137	
After 01/2014	$ 342,461	$ 76,404	
Difference	$ 73,914		
DF: 102			

Roulette AGP	Mean	Std. Dev.	***
Before 01/2014	$ 70,830	$ 19,246	
After 01/2014	$ 94,372	$ 26,400	
Difference	$ 23,542		
DF: 106			

Slots Drop	Mean	Std. Dev.	*
Before 01/2014	$ 161,764,352	$ 17,500,000	
After 01/2014	$ 156,034,464	$ 16,200,000	
Difference	$ (5,729,888)		
DF: 106			

Slots AGP	Mean	Std. Dev.	
Before 01/2014	$ 10,205,563	$ 1,117,637	
After 01/2014	$ 10,015,734	$ 1,089,588	
Difference	$ (189,829)		
DF: 108			

*p<=.05; **p<=.01; ***p<=.001

Total AGP	Mean	Std. Dev.	
Before 01/2014	$ 11,034,881	$ 1,199,855	
After 01/2014	$ 10,946,754	$ 1,149,117	
Difference	$ (88,127)		
DF: 108			

Change in Monthly Mean Gambling Metrics Before and After Legalization

Cripple Creek	Craps	Poker	Blackjack	Roulette	Total Coins In	Total AGP
% Change Drop	-7.2%	4.5%	-1.1%	27.5%	-3.5%	n/a
% Change AGP	4.2%	11.0%	34.5%	33.2%	-1.9%	-0.8%

Cripple Creek is Colorado's second largest gambling city, with monthly AGP averaging 20-25% of Black Hawk's monthly AGP. In contrast to Central City and Black Hawk, the mean drop metrics go up and down for Cripple Creek – roulette and poker experienced increased means by 27.5% and 4.5%, respectively, while craps, slots, and blackjack experienced decreased means by -7.2%, -3.5%, and -1.1% , respectively. The gambling metric means that are not statistically

different from zero are Total AGP, Slot AGP, Craps AGP, and Poker Drop and Blackjack Drop. It is located in Teller County, which has no recreational nor medical cannabis sales due to a ban, and is an hour drive East from Colorado Springs, which has only medical cannabis sales and which is the second most populous city in Colorado behind Denver. Although Teller County is small with an average population of 24,000 people between 2014 and 2018, it borders El Paso County, Colorado Spring's county, which is also the second most populous county behind Denver County. There is a city just outside Colorado Springs that has recreational cannabis sales – Manitou Springs – but there are only two retail shops there and, as such, El Paso County has no reported recreational cannabis sales that can be used in this analysis. When speaking to employees at the medical facilities in Colorado Springs, I was told that people who want to purchase recreational cannabis travel two hours north to Denver or travel an hour and a half south to Pueblo, where recreational cannabis is half the price and of much better quality than what can be purchased in Manitou Springs. The individual regressions run in Appendix 3D in the appendix seem to verify this idea – the cannabis retail sales in Denver and in Pueblo are very much related to Cripple Creek's gambling metrics.
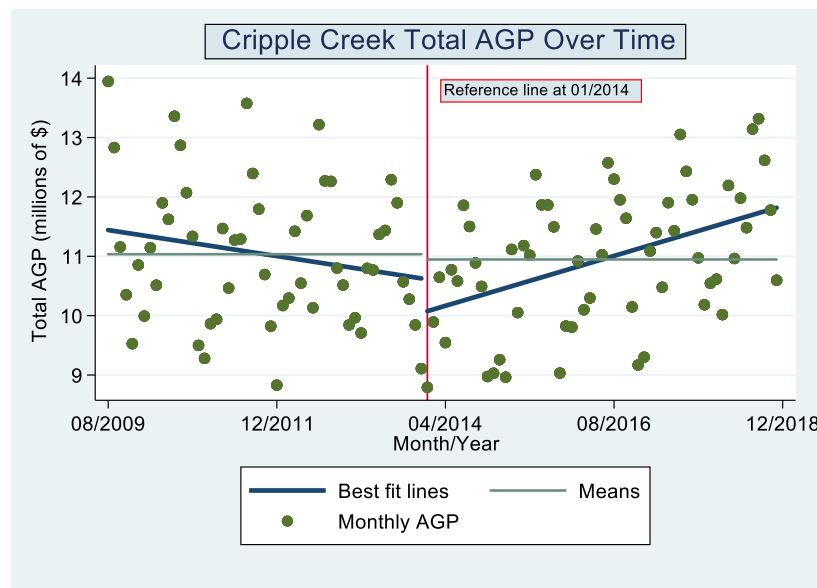
More than 90% of Cripple Creek's Total AGP is from slot machines, and, as you can see from this graph, although the difference in means is not statistically different from zero, there is a

noticeable difference in the slopes of the best fit lines of the before and after groups, which is similar to Black Hawk's Total AGP Over Time Graph

Briefing on limitations before going into regressions:

The data I have collected is difficult to work with because I have county specific cannabis retail sales and city specific gambling metrics. A city's gambling revenues are not solely a result of that specific county's expenditure on gambling, but rather a result of both residents in the entire state and visitors' gambling expenditure. There is no way that the monthly average slot machine revenue of $43MM+ in Black Hawk, Colorado's largest gambling city, can be derived primarily from the average population of 5,900 people that live in Gilpin County, Black Hawk's city. As such, there are people living in every county and visitors to each county that spend money at the various gambling locations. It should make sense then that each county is responsible for a portion of gambling expenditure and therefore, revenue, in each gambling city. I am unable to decipher what that proportion for all counties are, but if I could, then I could reasonably estimate the effects cannabis retail sales within the average Colorado county have on that county's gambling expenditure. I continue with this analysis, which is only a problem in the panel regressions I run, because, as I am not changing the variation of gambling metrics per county, it provides a legitimate relationship between cannabis retail sales and a specific gambling metric, and it is useful to compare the results for different games. The money spent on recreational cannabis in each county of Colorado is also a result of the purchases from visitors and people living in other counties – albeit to a much lesser extent than the money spent in the gambling cities. I conduct multivariate time series regressions of state gambling metrics on state cannabis retail to get a general idea of the relationship between statewide cannabis sales and statewide gambling metrics. I conduct multivariate time series regressions for city specific gambling metrics on state cannabis retail to get an understanding of how statewide cannabis retail sales relate to each specific city differently. I run

panel regressions with county and time fixed effects for state gambling metrics on county cannabis retail, and for city gambling metrics on county cannabis retail sales, with separate regressions for each city. To reduce variance and for ease of interpretation, I have log transformed the data - regressions are log-log and by nature allow for great differences in the size of x and y variables. This helps me better understand what the elasticities between gambling metrics and cannabis retail sales are in the city-sate and state-county regressions and formats my interpretations into "a 1% increase in cannabis retail sales relates to an x% change in a specific gambling metric".

I begin by both including the Adjusted Gross Proceeds and Drop for each game in the state level regressions, to demonstrate that typically the coefficient on cannabis retail sales for AGP regressions is greater than the coefficient for the respective Drop regressions and that the significance of AGP regressions is less than the Drop regressions. The difference between the coefficients and the degree of significance of the Drop and AGP regressions is determined by constant changes to casino strategy and other factors outside of public knowledge. This being the case, the elasticity between gambling and cannabis sales is determined from the drop regressions, not the AGP regressions. But when I move on to the county specific regressions, I utilize different regression models for the individual game AGP regressions because studying the relationship between cannabis sales and casino proceeds or revenue can only be done by including a game's drop amount as an independent variable.

State regressions:

The first group of regressions I test is a multivariate time series for each aggregate state gambling metric on statewide cannabis retail sales. These regressions take the form of:

(1) $\quad LogStateGM = \beta_0 + \beta_1 LogStateRS_t + \beta_2 StateDevices_t + \beta_3 Time_t + \varepsilon_t$

The dependent variable is the logarithm of a state gambling metric, and the independent variable of interest is the logarithm of statewide cannabis retail sales. I control for time because of the linear trend over time and also control for the total number of tables or machines dedicated to that respective game. There are only 59 months observed in these regressions because recreational cannabis sales have only existed since January, 2014. This being the case, I run these regressions to understand what the simple relationships between state gambling metrics and state cannabis sales are. Robust standard errors are in parentheses. See Appendix 1C for table results.

The interpretation of these results is not as important as understanding how the coefficient on cannabis retail sales differs in size and significance for each dependent variable. Regardless, the interpretation of this is that, holding time and number of devices constant, a 1% increase in mean statewide cannabis retail sales, around $668,000, is related to a .252% increase in mean statewide Blackjack Drop, approximately $41,600, and is related to a .174% increase in mean statewide Slots Drop, around $1.4 million, which is high. In order of elasticities, Blackjack Drop is most related to state cannabis retail sales at 0.252, followed by Poker Drop at 0.208 and Roulette Drop at 0.201, then Slots Drop at 0.174 and Craps Drop at .125. Every coefficient has a positive sign and each Drop metric is significant at least at the .05 level. Comparing the significant AGP regressions to the Drop regressions, each AGP regression, except for Blackjack, has a higher coefficient than its respective Drop regression coefficient. I revisit this is in the fixed effects panel regressions with a new model to figure out what the relationship between cannabis sales and actual gambling proceeds are.

The second group of regressions tested is a multivariate time series model for each gambling city metric on statewide cannabis retail sales:

(2) $LogCityGM_t = \beta_0 + \beta_1 LogStateRS_t + \beta_2 CityDevices_t + \beta_3 Time_t + \varepsilon_t$

For each gambling city – Black Hawk, Central City, Cripple Creek – I run this regression for all gaming metrics to see how the state's cannabis retail sales relate to the gaming metrics in each individual city. This builds on the first regression group (1) by giving insight into the cities driving the relationships seen on the state level. Robust standard errors are in parentheses. There are a total of 59 observations. See Appendix 2C for table results.

The purpose of performing these regressions is to see how statewide cannabis retail sales are related to each gambling cities' gaming metrics, not to interpret each one for a causal effect. Black Hawk has the most significant results, followed by Cripple Creek and then Central City. While every cities' Total AGP is significantly related to statewide cannabis sales, Black Hawk's coefficient on AGP is the most significantly different from zero, with a p-value of less than .001. Cripple Creek is significant at the 1% level and Central City is significant at the 5% level. Notice the similarities between the regressions of Total AGP and the regressions of Slot AGP – proceeds from slot machine gambling is responsible for the majority of each cities' Total AGP. For every Blackjack Drop regression, the coefficient on statewide cannabis retail sales is significantly different from zero at the .1% significance level. A 1% increase in statewide cannabis retail sales, around $668,000, is related to a .22% increase in Black Hawk Blackjack Drop, around $29,730, is related to a .284% increase in Central City Blackjack Drop, around $2,600, and is related to a .292% increase in Cripple Creek Blackjack Drop, around $6,070. These city estimates add up to $38,400 which is less than the estimated $41,600 increase in statewide Blackjack Drop found in the first group of regressions. The coefficient on state cannabis retail sales for the Roulette Drop regression in Cripple Creek is extremely high at .786%, which is driven primarily by the large and significant relationship of around 1.2% between cannabis retail sales in Denver and the Roulette Drop in Cripple Creek (see 3D in Appendix). This gives an example of how residents might travel to Denver to purchase cheaper products and how visitors might purchase in Denver before going south to the Colorado Springs area.

<u>County regressions:</u>

        The third group of regressions tested is a panel regression model with county fixed effects:

(3) $LogStateGM_t = \beta_0 + \beta_1 LogCountyRS_{it} + \beta_2 StateDevices_t + \beta_3 Time_t + \varepsilon_{it}$

        This model removes all time invariant characteristics and attempts to estimate what the true elasticities between cannabis retail sales and gambling drops are for Colorado during this time period. The Durbin-Wu-Hausman test confirmed a fixed effects model over a random effects model. Time is controlled so as to detrend the steady increase of variables over time and so are the number of tables or machines dedicated to the specific game in the state. Because y does not change by county, there is multicollinearity, but the model does not pick it up due to the fixed effects analysis. The dependent variable, the logarithm of a state gambling metric, remains the same for each county and changes over time, while the independent variable of interest, the logarithm of cannabis retail sales, will change by county and over time. This group of regressions is discussed previously but the idea is that, as each county is responsible for a specific amount of a statewide gambling metric, one can use a county's cannabis retail sales to help estimate the elasticity between cannabis sales and a gambling metric. It is unknown what portion of the state's gambling expenditure can be derived from each county, so the entire metric is used for each county. Since the only thing of concern is how one varies with the other, the size of a state or city gambling metric compared to a county's cannabis sales need not be important – the log transformation renders difference in sizes between independent and dependent variables a nonfactor in this analysis. For all the panel regressions, there are 1,393 observations with 32 counties and an average of 43.5 months per county. In these panel county fixed effects regressions I weight for the population of each county so that the relationship between cannabis retail sales in Denver County and gambling metrics influences the

regression results more than the cannabis retail sales in Montezuma County and Las Animas do. This way, the border counties with large recreational cannabis sales and many observations relative to their populations, like Montezuma, Las Animas and La Plata, don't over influence the relationships between gambling and cannabis that we want to study. The robust standard errors are in parentheses.

Table 2: State gambling metrics on county cannabis retail sales panel fixed effects regressions

Log State Gambling Metric	Log County Cannabis Retail Sales	R-Sq
Craps Drop	0.055 ***	0.47
	(0.011)	
Poker Drop	0.094 ***	0.48
	(0.024)	
Blackjack Drop	0.081 ***	0.37
	(0.015)	
Roulette Drop	0.064 ***	0.8
	(0.013)	
Slots Drop	0.083 ***	0.15
	(0.016)	
Total AGP	0.091 ***	0.28
	(0.015)	
*p<=.05; **p<=.01; ***p<=.001		

With the added data points, every coefficient is significant at the .001 level. In order of highest elasticities for the drop metrics, Poker Drop is first with .094, followed by Slots Drop at .083 and Blackjack Drop at .081, then Roulette Drop and Craps Drop are next at .064 and .055 elasticity, respectively. For Blackjack Drop, the interpretation of the elasticity in this regression, is that a 1% increase in a county's cannabis retail sales, around $26,700 of a monthly mean of $2,669,278, results in a .081% increase in Blackjack Drop holding all else constant. As this one county is not fully responsible for the statewide monthly mean of $16,509,923, it does not make sense to interpret this result as meaning that statewide Blackjack Drop would increase by around $13,300. It makes much less sense for the $26,700 increase in the mean expenditure on retail cannabis for a county to result in a .083% increase in the $805,749,568 mean statewide monthly Slot Drop, which would be around $670,000. A fraction of statewide means would make more sense. Here, if one

were able to derive gambling metrics per county, then this analysis could be more useful, and the resulting elasticities would also be different.

This next regression model follows a similar format of the previous panel regression (3), with the addition of one independent variable, and is unique for the AGP elasticity estimation. The biggest predictor of a casino's revenue for a game is the drop amount. By including a game's drop amount, we are testing to see if any proceed variance that hasn't been described by the drop variance can be described with significance by cannabis retail sales. This particular regression focuses on the proceeds from statewide games, but city specific game proceeds will be discussed too.

$$(4) \quad LogStateAGP_t = \beta_0 + \beta_1 LogCRS_{it} + \beta_2 LogStateDrop_t + \beta_3 StateDevices_t + \beta_4 Time_t + \varepsilon_{it}$$

The y variable is the logarithm of statewide AGP for a specific type of game and changes over time but not by county. The first regressor is the logarithm of county cannabis retail sales and changes over time and by county. The second regressor is the logarithm of the statewide drop amount for the game addressed in y and changes over time but not by county. The third and fourth regressors, the number of devices or machines dedicated to the game of interest and time, respectively, are not variables of interest but are controls.

Table 3: State AGP on county cannabis retail sales and state drop panel fixed effects regressions

Log State AGP	Log County Cannabs Retail Sales	Log State Drop	R-Sq
Craps	0.006	0.405 ***	0.27
	(0.008)	(0.006)	
Poker	0.013	0.964 ***	0.62
	(0.007)	(0.015)	
Blackjack	-0.023 ***	0.823 ***	0.88
	(0.004)	(0.012)	
Roulette	0.014	1.381 ***	0.81
	(0.007)	(0.026)	
Slots	0.009 ***	1.039 ***	0.97
	(0.001)	(0.003)	
*p<=.05; **p<=.01; ***p<=.001			

The size, sign and significance of the coefficients on county cannabis retail sales are very interesting. Controlling for the amount dropped, cannabis sales in the state still have an impact on Blackjack and Slots AGP with significance at the .1% level. Ceteris paribus, a 1% increase in a county's cannabis retail sales is associated with a 0.023% decrease in the state's Adjusted Gross Proceeds from Blackjack Drop and a .009% increase in the state's AGP from Slots Drop. The r^2 is extremely high for Blackjack and Slots AGP regressions – at 88% and 97%, almost all of the variance in the dependent variables is being described by the regressors.

The fifth group of regressions I run is the same as the third group of regressions (3), except it is a separate panel, county fixed effects regression for each gambling city's gaming metrics rather than for each of the entire state's aggregate gambling metrics:

(5) $LogCityGM_t = \beta_0 + \beta_1 LogCountyRS_{it} + \beta_2 CityDevices_t + \beta_3 Time_t + \varepsilon_{it}$

For each regression there are 1,393 observations with 32 counties and an average of 43.5 observations per county. I control for time and number of devices. The same problems are evident in this regression model as the ones in the previous county panel regressions. Robust standard errors are in parentheses.

Table 4: City gambling drop on county cannabis retail sales panel fixed effects regressions

Log Black Hawk Gambling Metric	Log County Cannabis Retail Sales	R-Sq	Log Central City Gambling Metric	Log County Cannabis Retail Sales	R-Sq	Log Cripple Creek Gambling Metric	Log County Cannabis Retail Sales	R-Sq
Craps Drop	0.053 ***	0.47	Craps Drop	-0.008	0.27	Craps Drop	0.025	0.41
	(0.014)			(0.015)			(0.031)	
Poker Drop	0.094 **	0.56	Poker Drop	0.156 **	0.70	Poker Drop	0.080 **	0.04
	(0.028)			(0.046)			(0.024)	
Blackjack Drop	0.083 ***	0.45	Blackjack Drop	0.080 ***	0.39	Blackjack Drop	0.123 ***	0.12
	(0.019)			(0.018)			(0.014)	
Roulette Drop	0.047 ***	0.85	Roulette Drop	0.072 *	0.22	Roulette Drop	0.385 ***	0.30
	(0.011)			(0.034)			(0.071)	
Slots Drop	0.080 ***	0.09	Slots Drop	0.074 ***	0.44	Slots Drop	0.102 ***	0.24
	(0.016)			(0.013)			(0.018)	
Total AGP	0.089 ***	0.24	Total AGP	0.085 ***	0.46	Total AGP	0.115 ***	0.24
	(0.016)			(0.013)			(0.017)	
*p<=.05; **p<=.01; ***p<=.001			*p<=.05; **p<=.01; ***p<=.001			*p<=.05; **p<=.01; ***p<=.001		

From these regressions, much of what was noticed in the city on state regressions, found in Appendix 2C, is repeated – Black Hawk still has the most significant number of regressions and the order of coefficient sizes for each variable in each city is the same. For Black Hawk, the regressions with highest coefficients are Poker Drop at .094%, followed by Blackjack Drop at .083% and Slots Drop at .08%, then Craps Drop at 0.053% and lastly Roulette Drop at .047%, which is the same order as Appendix 2C. For Central City, the order of the Drop regressions with the highest coefficients are Poker at 0.156%, Blackjack at .08%, Slots at .074%, and Roulette at 0.072%, which is the same order as in Appendix 2C. For Cripple Creek, the order of the drop regressions with the highest coefficients are Roulette at .385%, Blackjack at .123%, Slots at .102%, and then Poker at .08%, which is the same as in Appendix 2C except that, in the city on state regressions, Poker Drop isn't significant at any of my alphas. Blackjack elasticity on cannabis is highest in Cripple Creek (.123), followed by Black Hawk (.083) and Central City (.08). Cripple Creek has the highest Total AGP (.115) elasticity, followed by Black Hawk's Total AGP elasticity of .089 and Central City's Total AGP elasticity of .085. Comparing Black Hawk to Cripple Creek, the coefficients on Blackjack Drop through Total AGP are higher in Cripple Creek than in Black Hawk and are significant at the .1% level.

The final group of regressions is derived from the fourth group (4), but applied to each gambling city. So the analysis is looking at how the AGP for each game by city is related to county

cannabis retail sales holding the drop amount for the specific game constant as well. Robust

standard errors are in parentheses.

(6) $LogCityAGP_t = \beta_0 + \beta_1 LogCRS_{it} + \beta_2 LogCityDrop_t + \beta_3 CityDevices_t + \beta_4 time_t + \varepsilon_{it}$

Table 7: City AGP on county cannabis retail sales and city drop panel fixed effects regressions

Log BH AGP	Log County Retail Sales	Log BH Drop	R-Sq	Log CenC AGP	Log County Retail Sales	Log CenC Drop	R-Sq	Log CriC AGP	Log County Retail Sales	Log CriC Drop	R-Sq
Craps	0.028 **	0.158 ***	0.18	Craps	-0.091 **	1.441 ***	0.28	Craps	-0.089 **	0.611 ***	0.31
	(0.008)	(0.008)			(0.030)	(0.007)			(0.026)	(0.016)	
Poker	0.003	1.051 ***	0.62	Poker	-0.196 ***	0.953 ***	0.46	Poker	-0.037 *	0.703 ***	0.19
	(0.007)	(0.019)			(0.028)	(0.021)			(0.015)	(0.014)	
Blackjack	-0.025 ***	0.776 ***	0.9	Blackjack	-0.079 ***	0.989 ***	0.4	Blackjack	0.048 *	0.813 ***	0.59
	(0.004)	(0.010)			(0.017)	(0.030)			(0.018)	(0.021)	
Roulette	0.035 **	1.326 ***	0.81	Roulette	0.030	0.525 ***	0.19	Roulette	0.042	0.919 ***	0.62
	(0.013)	(0.038)			(0.035)	(0.003)			(0.023)	(0.011)	
Slots	0.010 ***	1.035 ***	0.96	Slots	0.012 **	1.015 ***	0.92	Slots	0.012 ***	1.041 ***	0.97
	(0.001)	(0.004)			(0.004)	(0.004)			(0.002)	(0.002)	
*p<=.05; **p<=.01; ***p<=.001				*p<=.05; **p<=.01; ***p<=.001				*p<=.05; **p<=.01; ***p<=.001			

It is clear that a significant amount of variance in gambling proceeds is still described by

county cannabis retail sales, even when controlling for the amount dropped. If the elasticity

between a game's drop amount and cannabis retail sales is significantly greater than the elasticity

between the game's AGP and cannabis retail sales, there is a negative elasticity between a game's

AGP and cannabis retail sales holding constant the drop amount for that game. Observe the

elasticities of the drop and AGP for the Craps and Poker games in Cripple Creek and Central City,

and for the Blackjack games in Central City and Black Hawk in Appendix 2C. The elasticities for the

drop variables are, as expected, quite high, with the majority of them around 1.0.

Closing remarks:

An interesting phenomenon that should be mentioned is that distance of a county from a

gambling location is insignificant in determining whether or not a county's cannabis sales are

significantly related to a city's gambling drop amounts. If recreational cannabis sales causes a

change in gambling metrics directly, then the distance of a county to a gambling city should help determine the significance of the elasticity of a gambling city's metric and a county's recreational cannabis sales. However, there is no easily identifiable relationship between the proximity of a county to a gambling location and the likelihood of that county's recreational cannabis sales being related to a gambling metric at that specific location (Appendix D). One of the reasons we see no significance of distance in these regressions is that the growth of the industry is paralleled throughout the state in many of the counties. That is, each county's industry is likely expanding at similar rates and onboarding new customers at similar rates, resulting in comparable trends month to month within each county. Of course, the conglomeration of business and the rollout of holding company strategy to as many locations as possible could be a driving force of correlation amongst counties' recreational cannabis sales.

Appendix D is also useful in displaying the number of counties with legal recreational cannabis sales whose sales are significantly related to gambling drop for each game. Slot machine drop in each city is significantly related to recreational cannabis sales in at least 20 of the 32 counties at the 5% level. Central City has the least number of individual county regressions that are significant, while Black Hawk and Cripple Creek are very similar, save for the distinct differences in the Roulette Drop, where Black Hawk has nine individual significant county regressions and Cripple Creek has 22.

At the onset of this research, I wanted to understand the relationship between consumption of cannabis and gambling. The best way to do this would be by isolating a population and seeing how individuals' gambling habits changed after cannabis has been introduced to that population, all else staying the same. Comparing gambling revenue and sales to cannabis retail sales is not a good way to go about analyzing the intrinsic relationship between gambling and cannabis consumption for a variety of reasons: we don't know who exactly is doing the gambling and consuming the

cannabis (there could be zero overlap between the two demographics, they may just have similar spending habits and the trends over time may just be a coincidence); there are a lot of tourists entering Colorado to experiment with this new industry, but we don't know how many there are nor how many are gambling (the tourists coming to buy legal cannabis could account for a disproportionate amount of gambling expenditure and revenues); cannabis retail sales don't give an honest representation of the usage of cannabis (before and after cannabis legalization there is still a black market, and the prices of cannabis are ever-changing); and gambling expenditure from the three legal gambling cities does not represent all gambling in Colorado (there are tribal casinos that don't pay any taxes and aren't required to document gaming statistics, and there are illegal games and online games that I don't have information on). Because there are a number of variables I can't control for that influence gambling expenditure that are also correlated with cannabis retail sales, my models suffer from omitted variable bias. However, I am still able to observe the effects legalization of cannabis has had on the Colorado gambling industry, just not with the ability to extrapolate my results to the intrinsic elasticity between cannabis consumption and gambling. My analysis, rather than inferring causality ubiquitously between cannabis and gambling, uses Colorado as a case study to see how this newly legalized industry impacted Colorado's gambling industry.

I have proven that from January 2014 up until the end of 2018, cannabis recreational sales and gambling metrics are inextricably linked with each other. Via the map, there's a significant border effect with visitors coming across state lines to purchase recreational cannabis in Colorado border counties like Montezuma, Las Animas, La Plata and Larimer. All three gambling cities, Black Hawk, Central City, and Cripple Creek, have experienced increases in gambling metrics, with the most similar increases in slot machine gambling in these cities. The graphs in Appendix 2A and Appendix B clearly show that Black Hawk's gambling industry has been changed the most from cannabis legalization, followed close behind by Cripple Creek's industry and then much further

behind is Central City's gambling industry. All of the significant panel regressions show that drop amount is positively related to increases in cannabis retail sales. On the state level, every gambling metric has increased, primarily because of each metric's reliance on Black Hawk's gambling amounts. This supports the theory that tourism is a driving factor in gambling revenue. Each city had a noticeable increase in its total Adjusted Gross Proceeds post legalization. We also see from the AGP panel fixed effects regressions that while holding constant the drop amount, county cannabis retail sales still impact variation of the dependent variable. Over time, as cannabis becomes normalized, there will be a reduction in the tourists that come for this industry, and if there are less tourists, there are less people available to gamble, so it'll be interesting to see how the relationship between cannabis retail sales and certain gambling metrics fair in the future. Further research needs to be completed to understand what the intrinsic relationship between consumption of cannabis and gambling is, and until more states have legalized cannabis and prices become relatively steady, sales data won't be a good metric for estimating this intrinsic relationship.

Appendix 1A:
Monthly mean proportions of state gambling metrics before and after legalization

Monthly mean proportions of state **before** legalization - Drop

Region	Craps Drop	Poker Drop	Blackjack Drop	Roulette Drop	Total Coins In
Black Hawk	77.8%	80.4%	79.4%	83.8%	70.5%
Central City	9.2%	7.6%	6.3%	5.1%	9.5%
Cripple Creek	13.0%	12.0%	14.3%	11.1%	19.9%
State	100.0%	100.0%	100.0%	100.0%	100.0%

Monthly mean proportions of state **after** legalization - Drop

Region	Craps Drop	Poker Drop	Blackjack Drop	Roulette Drop	Total Coins In
Black Hawk	82.5%	87.7%	81.8%	88.2%	71.5%
Central City	6.7%	2.2%	5.6%	2.5%	9.1%
Cripple Creek	10.8%	10.1%	12.6%	9.2%	19.4%
State	100.0%	100.0%	100.0%	100.0%	100.0%

Monthly mean proportions of state **before** legalization - AGP

Region	Craps AGP	Poker AGP	Blackjack AGP	Roulette AGP	Slots AGP	Total AGP
Black Hawk	78.0%	80.8%	80.3%	82.9%	72.5%	73.4%
Central City	8.8%	6.6%	5.8%	5.1%	9.4%	9.1%
Cripple Creek	13.2%	12.5%	13.9%	12.0%	18.1%	17.5%
State	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Monthly mean proportions of state **after** legalization - AGP

Region	Craps AGP	Poker AGP	Blackjack AGP	Roulette AGP	Slots AGP	Total AGP
Black Hawk	82.0%	87.5%	81.7%	87.4%	73.6%	75.0%
Central City	6.1%	2.2%	5.1%	2.6%	9.3%	8.7%
Cripple Creek	11.8%	10.3%	13.2%	10.1%	17.1%	16.4%
State	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix 2A:
Monthly proportions of state AGP over time
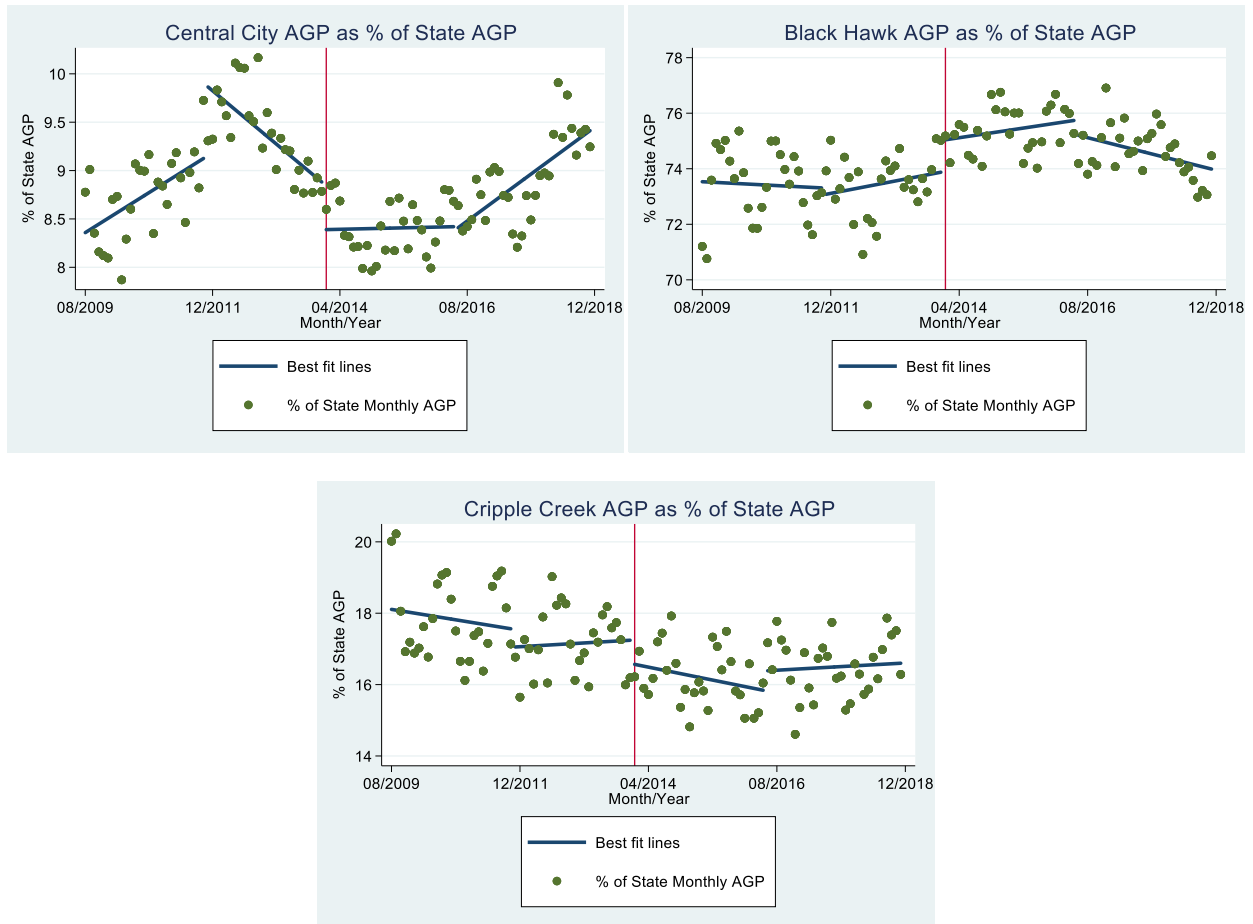
Note: Red reference line at January, 2014 – when cannabis was made recreationally legal.

Appendix 1B:
Colorado gambling metrics over time
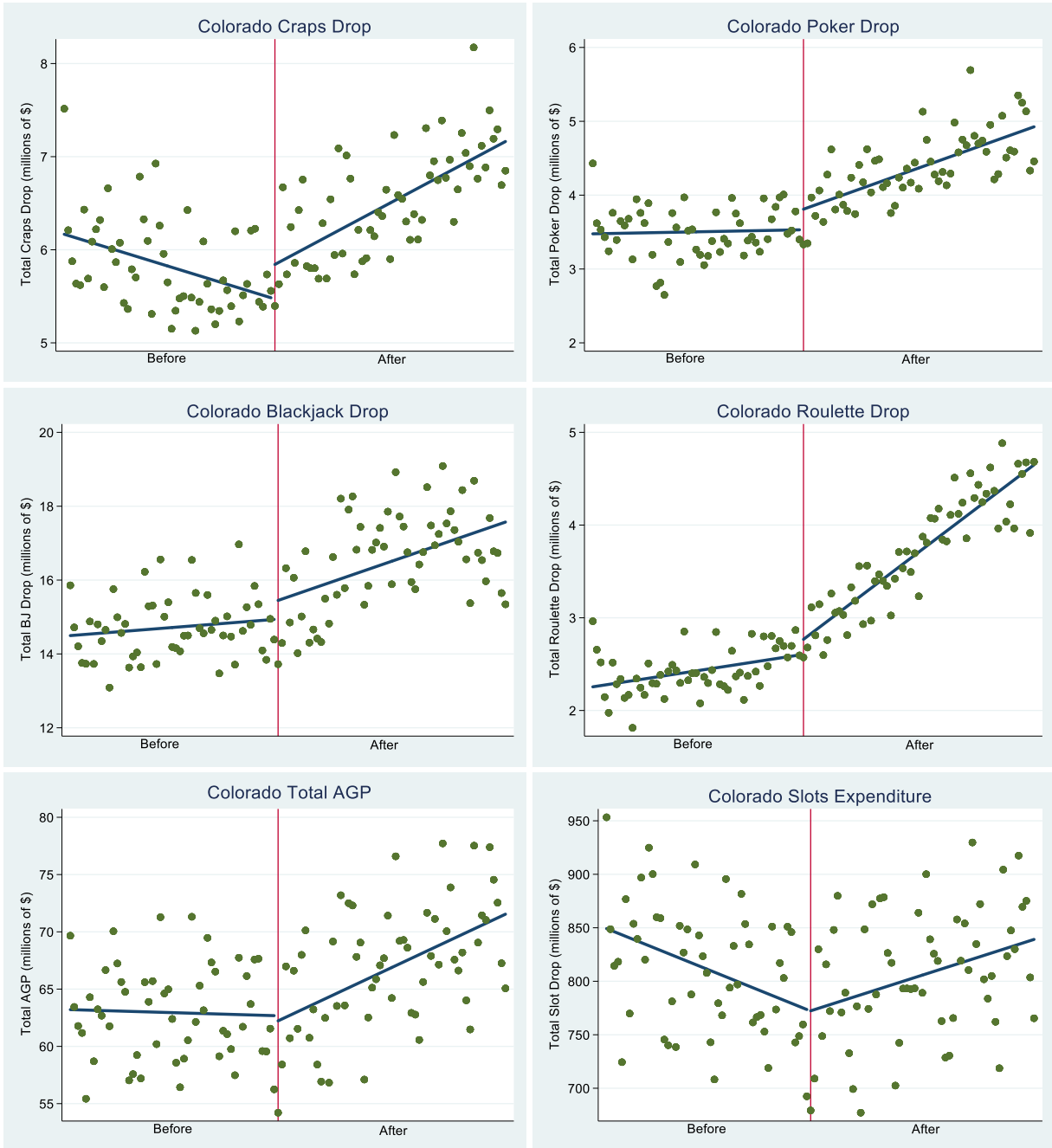
Note: Red reference line at January, 2014 – when cannabis was made recreationally legal.
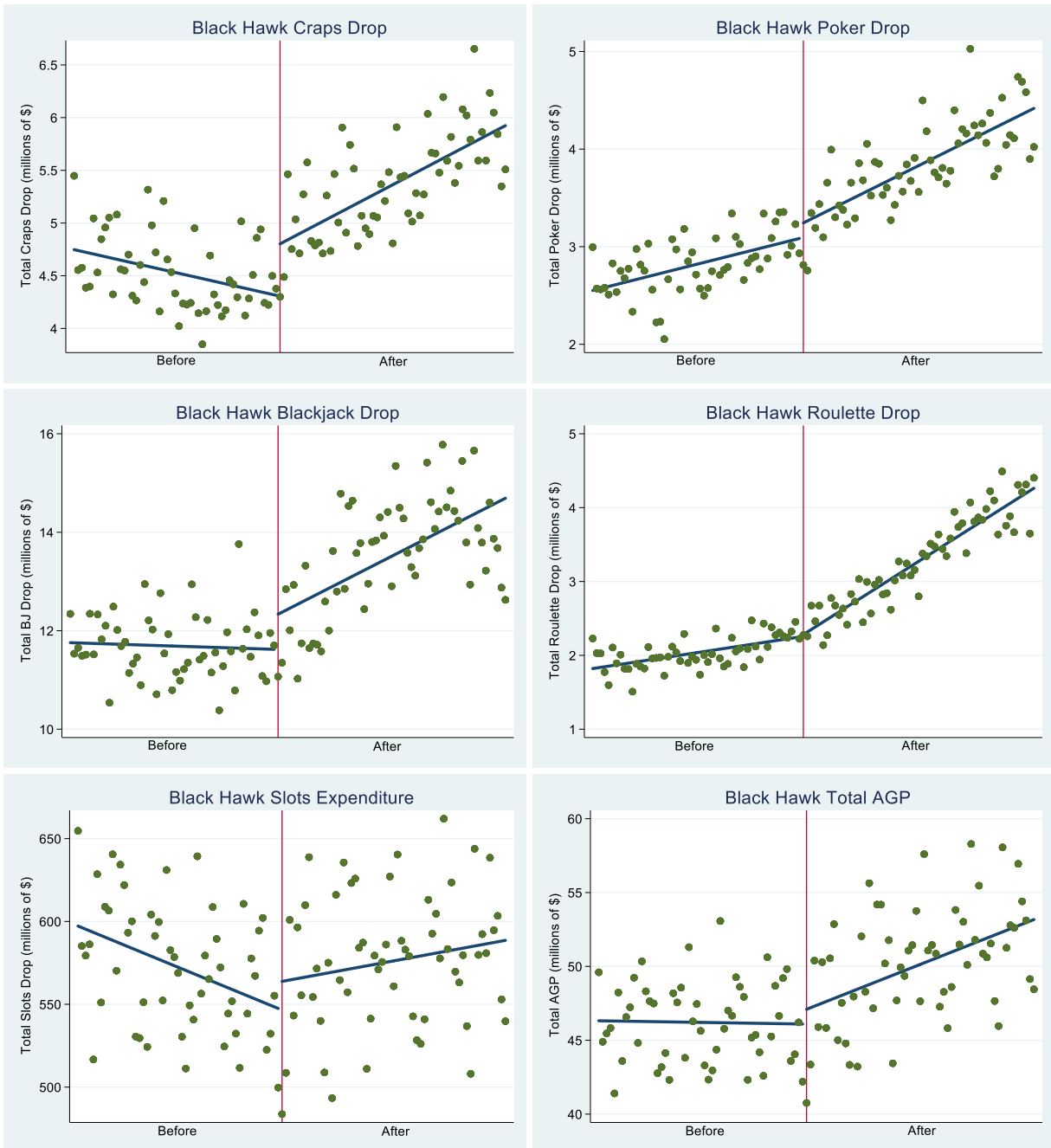
Note: Red reference line at January, 2014 – when cannabis was made recreationally legal.

Appendix 3B:
Central City gambling metrics over time
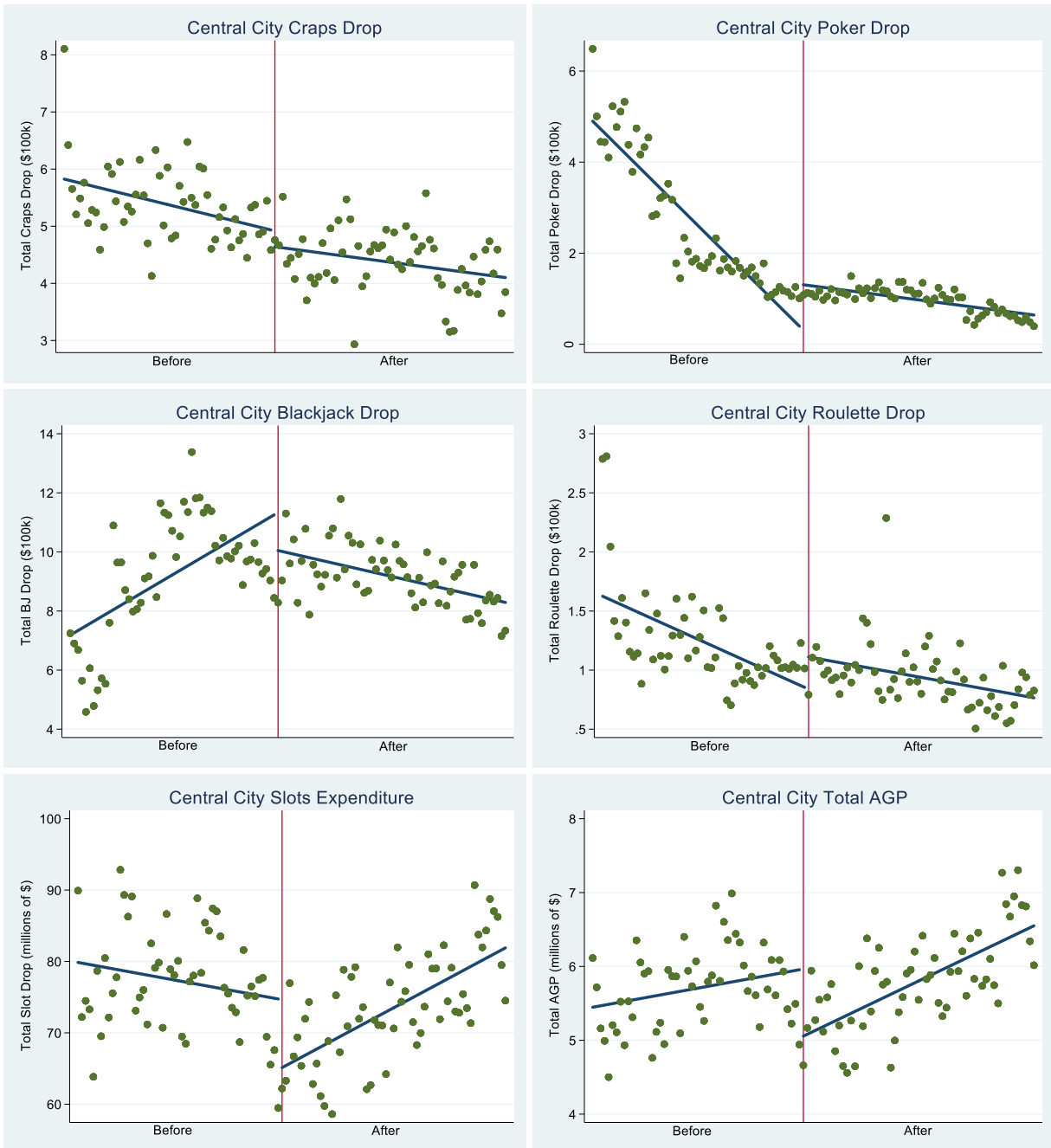
Note: Red reference line at January, 2014 – when cannabis was made recreationally legal.

Appendix 4B:
Cripple Creek gambling metrics over time
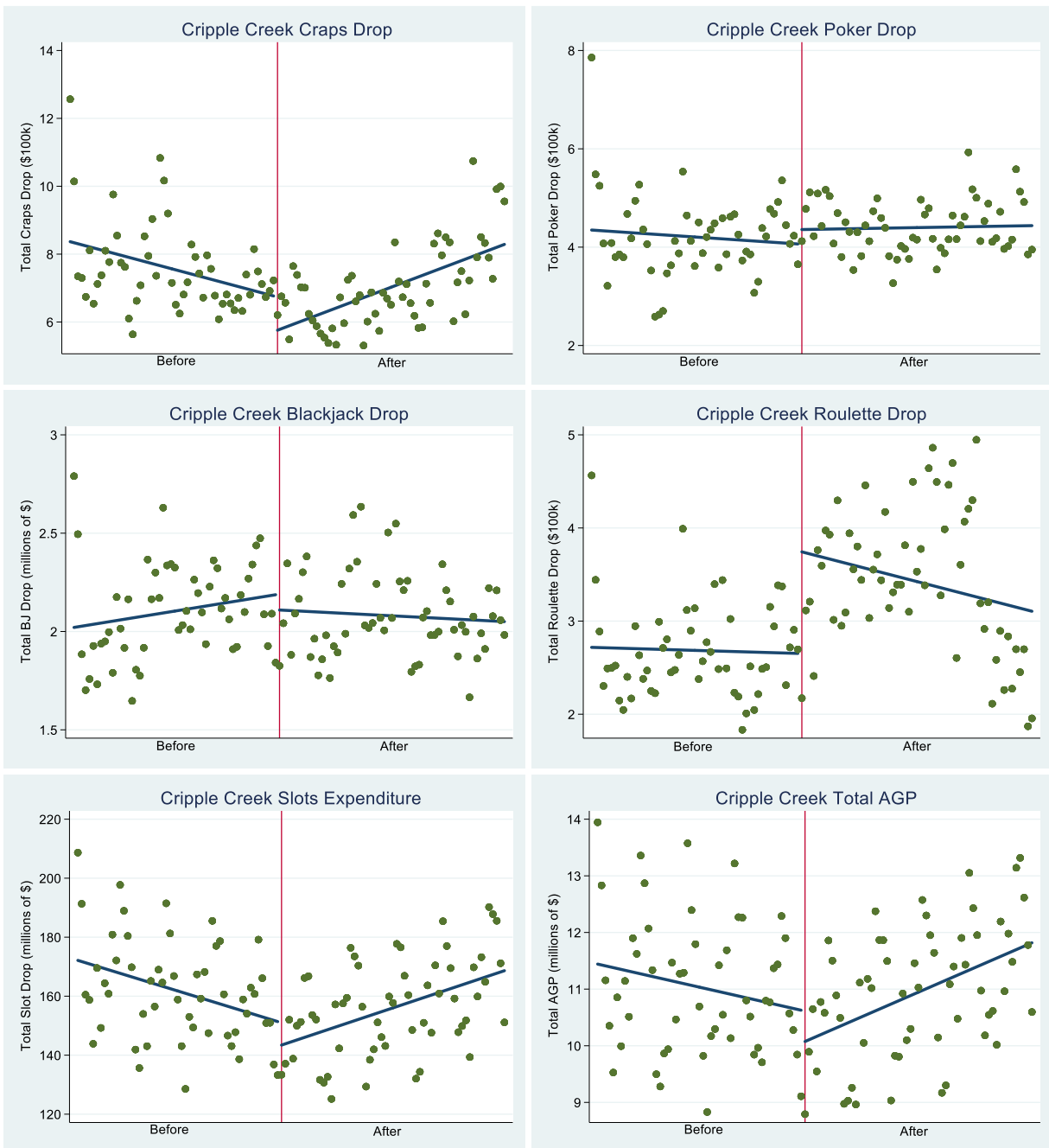
Note: Red reference line at January, 2014 – when cannabis was made recreationally legal.

Appendix 1C:
State gambling metrics on state cannabis retail sales regressions

Log State Gambling Metric	Log State Cannabis Retail Sales	R-Sq
Craps Drop	0.125 *	0.53
	(0.049)	
Craps AGP	0.071	0.27
	(0.065)	
Poker Drop	0.208 ***	0.63
	(0.039)	
Poker AGP	0.225 ***	0.47
	(0.064)	
Blackjack Drop	0.252 ***	0.57
	(0.049)	
Blackjack AGP	0.175 **	0.81
	(0.061)	
Roulette Drop	0.201 **	0.85
	(0.061)	
Roulette AGP	0.354 **	0.67
	(0.117)	
Slots Drop	0.174 ***	0.28
	(0.039)	
Slots AGP	0.191 ***	0.34
	(0.043)	
Total AGP	0.181 ***	0.41
	(0.041)	
*p<=.05; **p<=.01; ***p<=.001		

Appendix 2C:
City gambling metrics on state cannabis retail sales regressions

Log Black Hawk Gambling Metric	Log State Cannabis Retail Sales	R-Sq	Log Central City Gambling Metric	Log State Cannabis Retail Sales	R-Sq	Log Cripple Creek Gambling Metric	Log State Cannabis Retail Sales	R-Sq
Craps Drop	0.148 **	0.57	Craps Drop	-0.080	0.27	Craps Drop	-0.139	0.40
	(0.049)			(0.105)			(0.081)	
Craps AGP	0.094	0.25	Craps AGP	-0.309	0.07	Craps AGP	-0.230	0.20
	(0.067)			(0.340)			(0.127)	
Poker Drop	0.221 ***	0.71	Poker Drop	0.464 ***	0.74	Poker Drop	0.022	0.003
	(0.038)			(0.106)			(0.072)	
Poker AGP	0.237 **	0.50	Poker AGP	0.141	0.32	Poker AGP	-0.052	0.01
	(0.076)			(0.227)			(0.103)	
Blackjack Drop	0.220 ***	0.65	Blackjack Drop	0.284 ***	0.47	Blackjack Drop	0.292 ***	0.20
	(0.041)			(0.054)			(0.086)	
Blackjack AGP	0.130 *	0.84	Blackjack AGP	0.076	0.24	Blackjack AGP	0.465 ***	0.48
	(0.053)			(0.173)			(0.089)	
Roulette Drop	0.144 *	0.88	Roulette Drop	0.265	0.25	Roulette Drop	0.786 ***	0.52
	(0.066)			(0.146)			(0.122)	
Roulette AGP	0.338 *	0.72	Roulette AGP	0.305	0.09	Roulette AGP	0.816 ***	0.39
	(0.136)			(0.168)			(0.153)	
Slots Drop	0.162 ***	0.23	Slots Drop	0.161 *	0.48	Slots Drop	0.204 **	0.30
	(0.036)			(0.061)			(0.072)	
Slots AGP	0.179 ***	0.31	Slots AGP	0.163 *	0.53	Slots AGP	0.240 **	0.30
	(0.038)			(0.066)			(0.075)	
Total AGP	0.176 ***	0.40	Total AGP	0.170 *	0.50	Total AGP	0.230 **	0.40
	(0.036)			(0.067)			(0.070)	
*p<=.05; **p<=.01; ***p<=.001			*p<=.05; **p<=.01; ***p<=.001			*p<=.05; **p<=.01; ***p<=.001		

Significance of each gaming metric by city (according to p-value legend above):

Drop	BH	CenC	CriC	AGP	BH	CenC	CriC
Craps	**			Craps			
Poker	***	***		Poker	**		
BJ	***	***	***	BJ	*		***
Roulette	*		***	Roulette	*		***
Slots	***	*	**	Slots	***	*	**
				Total	***	*	**

Appendix 1D:
Black Hawk gambling drops on individual county cannabis retail sales regressions

County	Distance to Black Hawk	Log BJ Drop	BJ Drop P	Log Roulette Drop	Roulette Drop P	Log Craps Drop	Craps Drop P	Log Poker Drop	Poker Drop P	Log Slot Drop	Slots Drop P
Gilpin	4	0.087	0.060	-0.002	0.967	0.053	0.247	0.133	0.018	0.141	0.006
Clear Creek	11	0.136	0.013	0.120	0.048	0.166	0.004	0.179	0.009	0.144	0.011
*Jefferson	20	0.181	0.000	0.110	0.131	0.105	0.063	0.161	0.000	0.114	0.006
*Boulder	21	0.125	0.126	-0.027	0.739	0.067	0.415	0.197	0.023	0.149	0.076
*Denver	33	0.324	0.000	0.223	0.013	0.224	0.000	0.404	0.000	0.302	0.000
*Summit	35	0.032	0.240	0.076	0.011	0.045	0.109	0.019	0.525	-0.019	0.495
Grand	39	0.089	0.015	0.114	0.010	0.096	0.006	0.138	0.010	0.049	0.307
Park	48	0.178	0.000	0.139	0.024	0.120	0.004	0.220	0.000	0.160	0.001
*Larimer	60	0.349	0.000	0.215	0.029	0.122	0.138	0.172	0.057	0.182	0.037
Lake	61	0.135	0.009	0.089	0.080	0.128	0.007	0.220	0.001	0.172	0.011
*Adams	62	0.137	0.078	0.151	0.195	0.013	0.863	0.098	0.285	0.064	0.349
*Arapahoe	62	0.117	0.001	0.042	0.323	0.033	0.189	0.042	0.138	0.058	0.021
*Eagle	65	0.050	0.150	0.086	0.019	0.054	0.126	0.028	0.461	-0.011	0.749
*Weld	78	0.193	0.013	0.142	0.085	0.085	0.048	0.142	0.010	0.087	0.017
Chaffee	82	0.118	0.001	0.040	0.404	0.091	0.010	0.202	0.000	0.182	0.000
Pitkin	86	0.049	0.015	0.046	0.051	0.056	0.005	0.057	0.015	0.023	0.304
Routt	92	0.123	0.013	0.170	0.004	0.122	0.025	0.124	0.075	0.061	0.305
Morgan	95	0.450	0.000	0.146	0.292	0.154	0.208	0.495	0.001	0.565	0.000
Gunnison	114	0.074	0.052	0.075	0.054	0.078	0.021	0.112	0.010	0.101	0.004
*Pueblo	124	0.100	0.088	0.050	0.480	0.175	0.000	0.240	0.000	0.251	0.000
Saguache	126	0.117	0.112	-0.004	0.967	0.048	0.461	0.139	0.177	0.251	0.000
*Garfield	129	0.166	0.000	0.147	0.024	0.071	0.043	0.148	0.001	0.105	0.012
Ouray	167	0.138	0.003	-0.005	0.927	0.096	0.053	0.214	0.003	0.224	0.000
*Mesa	168	0.354	0.021	0.004	0.990	0.294	0.093	0.367	0.008	0.495	0.000
Costilla	174	0.123	0.000	0.047	0.301	0.088	0.011	0.214	0.000	0.174	0.000
Conejos	183	0.126	0.001	0.087	0.103	0.095	0.016	0.218	0.000	0.176	0.001
*Las Animas	189	0.161	0.000	0.071	0.100	0.047	0.135	0.089	0.028	0.094	0.017
Archuleta	199	0.163	0.001	0.100	0.133	0.144	0.004	0.225	0.002	0.206	0.003
San Miguel	200	0.015	0.507	0.035	0.136	0.049	0.018	0.059	0.026	0.040	0.079
*La Plata	215	0.231	0.000	0.115	0.114	0.108	0.022	0.166	0.003	0.177	0.000
*Montezuma	239	0.157	0.000	0.077	0.134	0.057	0.087	0.102	0.015	0.104	0.006
Number of significant results (.05)			22		9		17		24		23

Note: Highlighted parts are p-values of less than or equal to .05. Counties are ordered by distance.

* Denotes counties with average monthly recreational cannabis sales of greater than $1,000,000

Appendix 2D:
Central City gambling drops on individual county cannabis retail sales regressions

County	Distance to Central City	Log BJ Drop	BJ Drop P	Log Roulette Drop	Roulette Drop P	Log Craps Drop	Craps Drop P	Log Poker Drop	Poker Drop P	Log Slots Drop	Slots Drop P
Gilpin	4	0.051	0.421	0.033	0.818	-0.004	0.961	0.049	0.710	0.173	0.003
Clear Creek	10	0.177	0.019	0.093	0.581	0.231	0.010	0.175	0.254	0.215	0.001
*Jefferson	20	0.214	0.001	0.239	0.056	-0.083	0.472	0.459	0.000	0.122	0.184
*Boulder	22	0.100	0.432	0.131	0.434	-0.098	0.453	0.351	0.004	0.073	0.557
*Summit	34	0.057	0.173	0.026	0.737	0.110	0.005	0.201	0.006	-0.002	0.954
*Denver	34	0.320	0.000	0.283	0.206	-0.211	0.135	0.404	0.013	0.284	0.001
Grand	38	0.113	0.026	-0.030	0.839	0.096	0.143	0.143	0.281	0.038	0.425
Park	48	0.161	0.002	-0.267	0.197	-0.022	0.847	0.071	0.678	0.210	0.000
*Larimer	60	0.337	0.000	0.398	0.087	-0.007	0.963	0.405	0.039	0.289	0.017
Lake	60	0.112	0.084	0.168	0.465	-0.109	0.376	-0.281	0.126	0.149	0.019
*Adams	63	0.155	0.117	-0.060	0.823	-0.128	0.423	0.292	0.182	0.004	0.976
*Arapahoe	63	0.092	0.005	0.076	0.300	0.016	0.796	0.207	0.007	0.071	0.074
*Eagle	64	0.076	0.158	0.045	0.670	0.091	0.057	0.242	0.016	-0.003	0.941
*Weld	79	0.181	0.006	0.175	0.149	0.003	0.972	0.410	0.000	0.112	0.136
Chaffee	81	0.111	0.025	-0.059	0.765	-0.054	0.622	-0.209	0.159	0.173	0.000
Pitkin	85	0.061	0.039	0.042	0.519	0.049	0.125	0.132	0.027	0.026	0.324
Routt	92	0.127	0.068	-0.040	0.813	0.064	0.435	0.278	0.055	0.078	0.243
Morgan	96	0.463	0.001	0.969	0.016	-0.473	0.100	-0.875	0.040	0.344	0.011
Gunnison	113	0.080	0.083	-0.099	0.359	0.029	0.680	0.027	0.786	0.117	0.009
*Pueblo	124	0.117	0.110	-0.079	0.571	0.087	0.214	-0.121	0.451	0.277	0.000
Saguache	125	0.132	0.283	0.304	0.065	0.003	0.986	-0.347	0.252	0.416	0.000
*Garfield	128	0.135	0.006	0.138	0.266	-0.072	0.453	0.237	0.056	0.202	0.007
Ouray	166	0.144	0.022	0.400	0.026	-0.092	0.458	-0.362	0.118	0.194	0.000
*Mesa	167	0.433	0.063	0.157	0.791	0.548	0.020	0.623	0.149	0.638	0.000
Costilla	174	0.105	0.024	0.127	0.449	-0.104	0.236	-0.227	0.116	0.160	0.000
Conejos	183	0.095	0.054	0.040	0.845	-0.134	0.191	-0.213	0.185	0.178	0.001
*Las Animas	189	0.084	0.013	-0.095	0.400	-0.083	0.260	0.122	0.291	0.114	0.028
Archuleta	198	0.154	0.039	-0.015	0.964	0.011	0.939	-0.186	0.308	0.138	0.117
San Miguel	199	0.025	0.353	-0.071	0.255	0.029	0.402	-0.010	0.861	0.057	0.018
*La Plata	214	0.191	0.001	0.122	0.439	0.008	0.944	0.213	0.141	0.260	0.000
*Montezuma	238	0.054	0.155	-0.140	0.326	-0.055	0.516	0.220	0.027	0.179	0.000
Number of significant results (.05)			17		2		3		11		20

Note: Highlighted parts are p-values of less than or equal to .05. Counties are ordered by distance.

* Denotes counties with average monthly recreational cannabis sales of greater than $1,000,000

Appendix 3D:
Cripple Creek gambling drops on individual county cannabis retail sales regressions

County	Distance to Cripple Creek	Log BJ Drop	BJ Drop P	Log Roulette Drop	Roulette Drop P	Log Craps Drop	Craps Drop P	Log Poker Drop	Poker Drop P	Log Slots Drop	Slot Drop P
Park	39	0.245	0.000	0.616	0.000	0.184	0.038	0.480	0.000	0.289	0.000
*Pueblo	54	0.399	0.000	0.235	0.048	0.491	0.000	0.617	0.000	0.422	0.000
Chaffee	55	0.235	0.000	0.359	0.032	0.209	0.013	0.394	0.000	0.323	0.000
*Jefferson	58	0.205	0.015	0.688	0.000	-0.166	0.017	-0.038	0.571	0.094	0.164
Clear Creek	70	0.275	0.000	0.287	0.105	0.163	0.151	0.360	0.000	0.255	0.000
Lake	70	0.242	0.020	0.312	0.079	0.207	0.082	0.474	0.000	0.368	0.000
*Denver	72	0.275	0.007	1.238	0.000	-0.085	0.521	0.203	0.095	0.411	0.000
Saguache	75	0.228	0.061	0.613	0.007	0.157	0.368	0.226	0.023	0.346	0.000
*Arapahoe	77	0.128	0.003	0.319	0.000	0.036	0.600	0.089	0.122	0.073	0.054
Gilpin	79	0.263	0.000	0.401	0.015	0.232	0.005	0.270	0.000	0.267	0.000
*Summit	79	-0.020	0.575	0.070	0.443	-0.111	0.048	-0.004	0.934	-0.068	0.029
*Adams	90	0.121	0.319	0.853	0.000	0.027	0.857	0.252	0.078	0.112	0.280
*Boulder	93	0.272	0.171	0.664	0.001	0.018	0.878	0.087	0.514	0.367	0.001
Pitkin	99	0.039	0.256	0.140	0.047	-0.050	0.260	0.062	0.137	0.026	0.405
Gunnison	100	0.184	0.000	0.334	0.001	0.075	0.199	0.250	0.000	0.180	0.000
*Eagle	101	-0.013	0.771	0.159	0.124	-0.116	0.064	0.021	0.701	-0.063	0.180
Costilla	102	0.214	0.001	0.395	0.011	0.234	0.007	0.340	0.000	0.320	0.000
Grand	106	0.052	0.438	0.191	0.139	-0.035	0.659	0.168	0.031	0.052	0.445
*Las Animas	117	0.132	0.003	0.435	0.000	0.092	0.148	0.250	0.002	0.129	0.001
Conejos	120	0.180	0.036	0.533	0.001	0.200	0.046	0.374	0.000	0.350	0.000
Morgan	128	0.517	0.014	0.965	0.009	0.839	0.001	0.704	0.001	0.610	0.000
*Weld	132	0.236	0.002	0.676	0.000	-0.107	0.323	-0.002	0.980	0.114	0.093
*Larimer	133	0.619	0.000	0.820	0.000	0.076	0.686	0.146	0.334	0.263	0.048
Ouray	146	0.313	0.001	0.199	0.346	0.358	0.006	0.411	0.000	0.395	0.000
Archuleta	148	0.248	0.000	0.603	0.001	0.212	0.086	0.408	0.000	0.248	0.000
Routt	154	0.103	0.165	0.316	0.068	0.014	0.901	0.251	0.006	0.098	0.198
*Garfield	157	0.177	0.002	0.596	0.000	-0.038	0.684	0.121	0.138	0.152	0.007
*La Plata	177	0.357	0.000	0.639	0.000	0.310	0.004	0.403	0.000	0.301	0.000
*Mesa	178	0.140	0.304	0.450	0.190	0.299	0.480	0.683	0.000	0.262	0.060
San Miguel	182	0.072	0.020	0.064	0.375	0.080	0.034	0.154	0.000	0.096	0.000
*Montezuma	210	0.143	0.002	0.474	0.000	0.095	0.166	0.319	0.000	0.127	0.005
Number of significant results (.05)			22		22		12		20		22

Note: Highlighted parts are p-values of less than or equal to .05. Counties are ordered by distance.

* Denotes counties with average monthly recreational cannabis sales of greater than $1,000,000

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