Washington State Institute for Public Policy

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Technical Report—
Licensed Cannabis Retail Access and Traffic Fatalities

This Technical Report details one of several outcome analyses related to WSIPP's long-term evaluation of non-medical cannabis (NMC) legalization in Washington. For a full description of findings from all analyses we conducted in 2023, please refer to Initiative 502 and Cannabis-Related Public Health and Safety Outcomes: *Third Required Report*.[1] For more background information about Initiative 502 and related cannabis policy, please refer to our previously published report, A 10-Year Review of Non-Medical Cannabis Policy, Revenues, and Expenditures.[2]

In November 2012, Washington State voters passed Initiative 502 (I-502), which legalized limited possession, private use, and retail sales of cannabis for adults.[3] The law also directed the Washington State Institute for Public Policy (WSIPP) to conduct a benefit-cost evaluation of the implementation of I-502 that should consider (among other things) *public safety*. One aspect of public safety that may be influenced by cannabis legalization relates to cannabis-impaired driving and traffic fatalities.

In this technical report, we provide a comprehensive description of our evaluation of the relationship between access to licensed non-medical cannabis (NMC) retailers in Washington and the prevalence of traffic fatalities and THC-positive driver involvement. Specifically, we examine the relationship between the average drive time to the nearest NMC retailer in a ZIP code and involvement in a fatal traffic collision.

An abridged description of this analysis can be found in our main report.[4] This main report also summarizes key findings from related work focusing on reported substance use, substance use disorder, and criminal justice outcomes.

In Section I, we describe how cannabis use and NMC legalization relate to traffic safety and review the relevant literature. In Section II, we describe our data. In Sections III and IV, respectively, we describe our research design and results. In Section V, we discuss our findings and detail the limitations of our analysis.

Suggested citation: Rashid, A. (2023). *Technical report—Licensed cannabis retail access and traffic fatalities* (Document Number 23-09-3202). Olympia: Washington State Institute for Public Policy.

[1] Rashid, A. (2023). *Initiative 502 and cannabis-related public health and safety outcomes: Third required report* (Doc. No. 23-09-3201). Olympia: Washington State Institute for Public Policy.

[2] Ingraham, B., & Rashid, A. (2023). *A 10-year review of non-medical cannabis policy, revenues, and expenditures* (Doc. No. 23-06-3201). Olympia: Washington State Institute for Public Policy.

[3] Initiative Measure No. 502.

[4] Rashid (2023).

I. Background

At the same time Initiative-502 (I-502) legalized the possession and use of limited quantities of cannabis, laws prohibiting driving under the influence were amended to include a legal limit (i.e., *per se* level) of five nanograms per milliliter (ng/mL) delta-9-tetrahydrocannabinol (THC) in whole blood for drivers ages 21 and older.[5] Suspected impaired drivers can also be charged if it can be proven that the individual was under the influence of cannabis, regardless of THC blood concentration.[6] Impaired driving remains a primary concern related to cannabis legalization because impairments in driving performance could present a major threat to roadway safety. Second to alcohol, cannabis is the substance most frequently found in the blood of drivers involved in motor vehicle crashes.

Research on Impaired Driving

Cannabis Use and Driving Skills

Studies have generally found a modest relationship between cannabis intoxication and driving ability. Broadly, cannabis use has been linked to decreases in relevant psychomotor and neurocognitive performance. For example, experimental evidence has linked THC to impairments in memory, attention, concentration, executive function, and impulse control.[7] THC has also been linked to significant deterioration in visual acuity, contrast sensitivity, depth perception, focusing ability, and glare response.[8] Studies using a driving simulator have found that acute cannabis smoking relates to more driving errors, and combining alcohol with cannabis enhances impairment.[9]

Despite evidence linking cannabis use to relevant neurobehavioral effects, the ultimate relationship between cannabis use and road safety—particularly traffic fatalities—remains unknown. Determining the role of cannabis use in impaired driving and motor vehicle collisions is challenging for several reasons. Notably, cannabis may be detected in body fluid for days or weeks after experiencing intoxication, making it difficult to identify current impairment.[10] Furthermore, unlike alcohol, cannabis may impact driving ability differently for those who engage in occasional use compared to those who engage in frequent use.[11] For example, one study found that only occasional users, not daily users, exhibited diminished driving performance after acute cannabis smoking in comparison to non-users.[12] However, a different study found that generally, regular cannabis users displayed more driving errors than non-regular users.[13]

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[5] In Washington State, a zero tolerance was set for drivers under the age of 21.
[6] RCW 46.61.502.
[7] McCartney, D., Arkell, T.R., Irwin, C., & McGregor, I.S. (2021). Determining the magnitude and duration of acute Δ9-tetrahydrocannabinol (Δ9-THC)-induced driving and cognitive impairment: A systematic and meta-analytic review. *Neuroscience & Biobehavioral Reviews*, *126*, 175-193.
[8] Ortiz-Peregrina, S., Ortiz, C., Casares-López, M., Jiménez, J.R., & Anera, R.G. (2021). Effects of cannabis on visual function and self-perceived visual quality. *Scientific reports*, *11*(1), 1-11.
[9] Brooks-Russell, A., Brown, T., Friedman, K., Wrobel, J., Schwarz, J., Dooley, G., . . . Kosnett, M.J. (2021). Simulated driving performance among daily and occasional cannabis users. *Accident Analysis & Prevention*, *160*, 106326; Downey, L.A., King, R., Papafotiou, K., Swann, P., Ogden, E., Boorman, M., & Stough, C. (2013). The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. *Accident Analysis & Prevention*, *50*, 879-886; and Hartman, R.L., & Huestis, M.A. (2013). Cannabis effects on driving skills. *Clinical chemistry*, *59*(3), 478-492.
[10] Studies have also indicated that field sobriety tests alone serve as unreliable indicators of current cannabis intoxication: Fitzgerald, R.L., Umlauf, A., Hubbard, J.A., Hoffman, M.A., Sobolesky, P.M., Ellis, S.E., . . . Marcotte, T.D. (2023). Driving under the influence of cannabis: impact of combining toxicology testing with field sobriety tests. *Clinical chemistry*, hvad054.
[11] Downey et al. (2013).
[12] Brooks-Russell et al. (2021).
[13] Downey et al. (2013).

NMC Legalization and Traffic Fatalities

Although there is limited opportunity to directly evaluate the effect of cannabis use on traffic safety, a related body of literature has examined the relationship between cannabis *legalization* and traffic fatalities in Washington and other states. One study examining fatal crash outcomes in Washington State finds that the prevalence of THC-positive drivers involved in fatal crashes was higher after the enactment of I-502 relative to before.[14] However, other studies find no evidence that NMC legalization predicts increases in the overall prevalence of fatal crashes in Washington compared to traffic fatalities in similar states. These same studies find mixed results regarding NMC legalization and traffic fatalities in Colorado. A national study evaluating all NMC-legalizing states between 2007 and 2018 finds that fatal motor vehicle crashes and associated deaths are roughly 15% higher in NMC-legalizing states after legalization compared to non-legalizing states.[15] Another study finds that traffic fatalities did not change after NMC legalization but did significantly increase after the advent of retail sales.[16]

Ultimately, the evidence within this literature is inconclusive about the effect of cannabis legalization on traffic fatalities. The differences in results across studies could be due to several factors, including differences in data quality, different choices for state comparisons and research design, and different study periods. Several of these studies examine outcomes after the first few years of NMC legalization.

Current Study

In this study, we expand upon the existing literature by examining if greater local access to licensed NMC retailers predicts differences in the number of traffic fatalities.

We expect greater access to legal cannabis to impact traffic fatalities if cannabis use and subsequent impaired driving increases with access. Other studies have found that greater NMC retail access in a ZIP code—measured as the minimum average drive time/distance to the nearest retailer—predicts a higher likelihood of reported cannabis use over the years 2014-2016.[17] Using the same data and similar methodology, in analyses not presented here, we also find that a reduction in average drive time (measured in minutes) to the nearest retailer predicts greater reported cannabis use among adults ages 21 and older over the period 2014-2019.[18] In particular, we estimate that *a 50% reduction in the average drive time to the nearest NMC retailer is associated with a 6.1% increase in the probability of reporting past-month cannabis use and an 8.3% increase in the probability of reporting heavy past-month cannabis use.*[19]

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[14] Tefft, B.C., & Arnold, L.S. (2021). Estimating cannabis involvement in fatal crashes in Washington State before and after the legalization of recreational cannabis consumption using multiple imputation of missing values. *American Journal of Epidemiology*, *190*(12), 2582-2591.

[15] Windle, S.B., Eisenberg, M.J., Reynier, P., Cabaussel, J., Thombs, B.D., Grad, R., . . . Filion, K.B. (2021). Association between legalization of recreational cannabis and fatal motor vehicle collisions in the United States: an ecologic study. *Canadian Medical Association Open Access Journal*, *9*(1), E233-E241.

[16] Aydelotte, J.D., Mardock, A.L., Mancheski, C.A., Quamar, S.M., Teixeira, P.G., Brown, C.V., & Brown, L.H. (2019). Fatal crashes in the 5 years after recreational marijuana legalization in Colorado and Washington. *Accident Analysis & Prevention*, *132*, 105284.

[17] Ambrose, C.A., Cowan, B.W., & Rosenman, R.E. (2021). Geographical access to recreational marijuana. *Contemporary economic policy*, *39*(4), 778-807 and Everson, E.M., Dilley, J.A., Maher, J.E., & Mack, C.E. (2019). Post-legalization opening of retail cannabis stores and adult cannabis use in Washington State, 2009–2016. *American journal of public health*, *109*(9), 1294-1301.

[18] We use data provided by the Liquor and Cannabis Board (LCB) on the location and dates of operation for licensed NMC retailers in Washington and data on reported cannabis use from the Washington State Behavioral Risk and Surveillance System (BRFSS) which is provided by the Department of Health.

[19] More information about these analyses can be found in Rashid (2023).

Given that proximity to an NMC retailer predicts greater reported cannabis use, in this study, we examine if the prevalence of traffic fatalities changes among drivers residing in ZIP codes with a more proximate retailer. Specifically, we address the following three questions:

> *Question 1: Is a shorter average drive time to the nearest retailer in a ZIP code related to the number of drivers involved in fatal traffic collisions?*
>
> *Question 2: Is a shorter average drive time to the nearest retailer in a ZIP code related to the number of drivers involved in fatal traffic collisions who test positive for THC?*
>
> *Question 3: Is a shorter average drive time to the nearest retailer in a ZIP code related to the number of drivers involved in fatal traffic collisions who test positive for alcohol alone or in combination with THC?*

II. Data

Data on traffic fatalities come from the Washington Coded Fatal Crash (CFC) data files. These data comprise all recorded individuals and vehicles involved in motor vehicle crashes that occur on a public road in Washington State and result in a death within 30 days.[20] These data also include blood test results for intoxicants, including THC, from the state's centralized toxicology laboratory.

Our NMC retail access analyses only examine traffic fatality outcomes after the advent of licensed NMC operations in July 2014. However, we use data on all drivers involved in a fatal crash from January 1, 2008, through December 31, 2019, to describe fatality outcomes in this section.[21] In particular, we first describe trends in traffic fatalities starting in 2008. Second, we describe the characteristics of drivers and traffic incidents that occur during the study period of 2014-2019.

Traffic Fatality Trends

Overall Fatalities

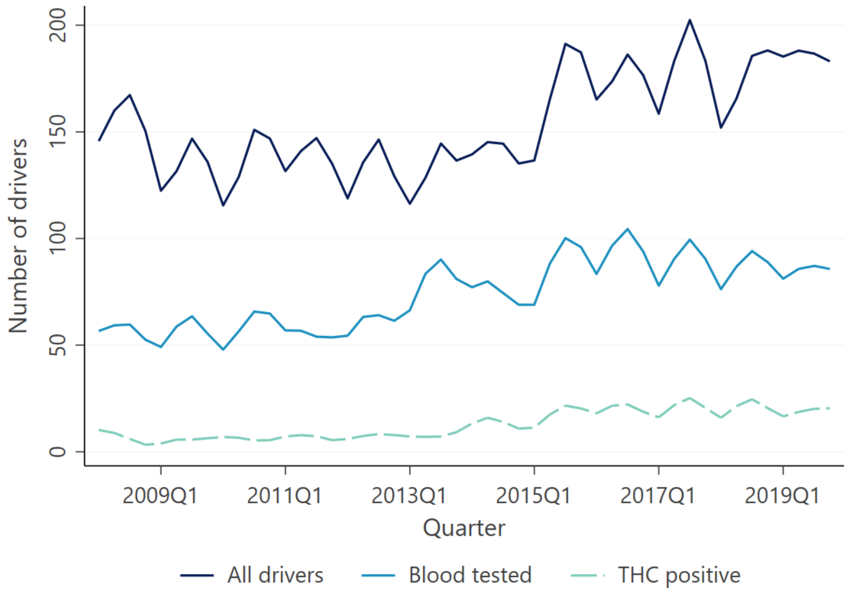
Between 2008 and 2019, 3,357 fatal traffic crashes occurred in Washington, involving a total of 8,266 drivers. The dark blue line in Exhibit 1 depicts the statewide quarterly number of drivers involved in a traffic fatality over time—on average, 172 drivers are involved in a fatal incident per quarter. Typically, traffic deaths decrease in the winter and increase in the summer, with the highest prevalence in the third quarter (July through September).

The quarterly number of drivers involved in fatal traffic collisions remained relatively steady through 2014, with an average of 155 drivers per quarter. In the third quarter of 2015, the number of drivers involved in fatal crashes increased and remained at an average of about 195 drivers per quarter through the close of 2019. We only observe THC content for drivers who receive a blood test—only 48% of drivers involved in a fatal crash received a blood test.[22] The light blue line in Exhibit 1 indicates that the average number of blood-tested drivers similarly increased in 2015 before plateauing at an average of about 95 drivers a quarter. Among blood-tested drivers, about 12 drivers per quarter test positive for the presence of THC (dashed line on Exhibit 1).

[20] This database is maintained and distributed by the Washington State Traffic Safety Commission.
[21] Blood test derived THC levels are not available prior to January 1, 2008.
[22] Roughly 75% of drivers that have received a blood test are deceased because of the collision. State law dictates that drivers and pedestrians killed within four hours of a fatal crash shall have their blood sample analyzed by the state toxicologist (RCW 46.52.065). Generally, a police officer needs a warrant to compel a blood test from a surviving driver (RCW 46.20.308).

Exhibit 1

Quarterly Number of Drivers Involved in Fatal Traffic Accidents, 2008-2019



Note:
Data come from the Coded Fatal Crash (CFC) data files, 2008-2019.

Intoxicant Tested Drivers

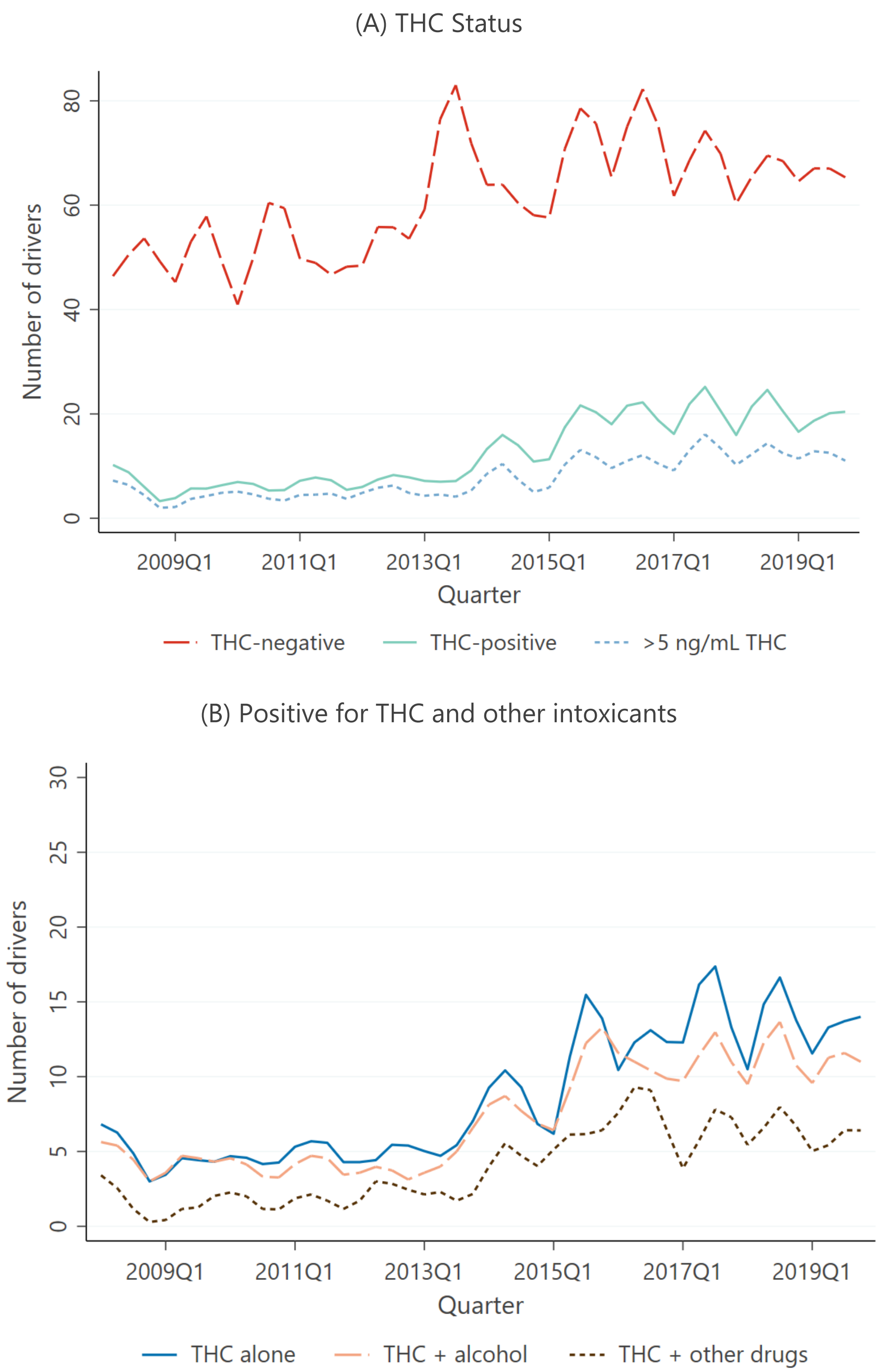
Among drivers who received a blood test, roughly 17% had a concentration of THC in whole blood of at least 1 ng/mL (i.e., THC-positive).[23] If a driver's blood was tested and THC was not detected, they are categorized as THC-negative. Panel A of Exhibit 2 depicts the quarterly number of blood-tested drivers by THC Status (positive/negative). Panel A also depicts the number of THC-positive with a THC concentration at or above the legal limit of 5 ng/mL of blood. CFC data also allow us to examine the prevalence of drivers who tested positive for THC alone and in combination with other intoxicants, as shown in Panel B.[24] Across all categorizations of drivers with a detectable amount of THC in the blood, there is a general upward trend in fatal collision involvement with a relatively large average increase in 2014.

[23] Procedures for the collection and coding of data pertaining to THC have been described by *Driver Toxicology Testing and the Involvement of Marijuana in Fatal Crashes, 2010-2014 (WTSC, 2016)*.

[24] Note, in Panel B of Exhibit 2, drivers who test positive for THC and alcohol (dashed line) may also test positive for other drugs. Likewise, drivers who test positive for THC and other drugs (the dotted line) may also test positive for alcohol.

Exhibit 2

Quarterly Number of Driver Involved in Fatal Traffic Accidents, by Blood Test Results 2008-2019

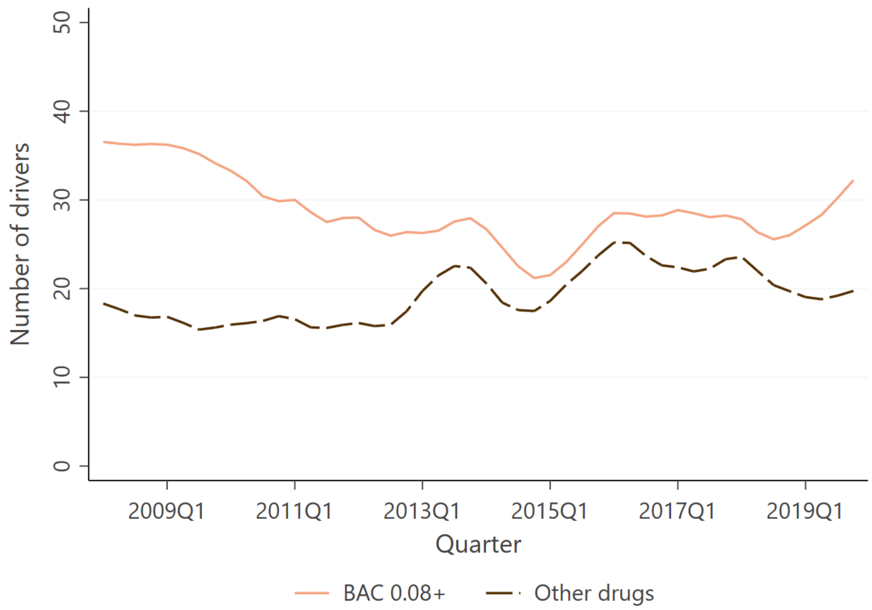


Notes:
Data come from the Coded Fatal Crash (CFC) data files, 2008-2019.
Other drugs include narcotics, depressants, stimulants, hallucinogens, and phencyclidine.

We can also describe the prevalence of drivers under the influence of other intoxicants. Exhibit 3 depicts trends among drivers who test positive for other drugs (excluding cannabinoids) and drivers who register a blood alcohol concentration (BAC) at or above 0.08.[25] Unlike upward trends in the prevalence of overall drivers and THC-positive drivers involved in a fatal crash, the prevalence of drivers with a BAC above the legal limit declined through 2015 and then remained at an average of about 27 drivers a quarter.

Exhibit 3

Quarterly Number of Drivers Involved in Fatal Traffic Accidents Positive for Non-cannabinoid Intoxicants, 2008-2019



Notes:
Data come from the Coded Fatal Crash (CFC) data files, 2008-2019.
Other drugs include narcotics, depressants, stimulants, hallucinogens, and phencyclidine.

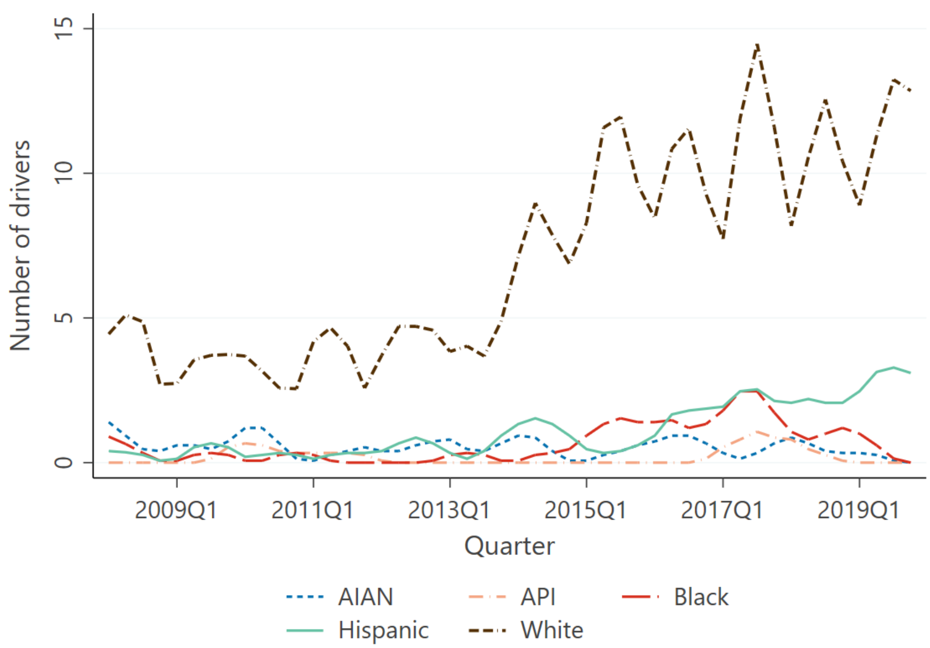
[25] 52% of drivers involved in a fatal crash between 2008-2019 were tested for the presence of alcohol.

Driver Demographics

The race or ethnicity of a driver is derived from the death certificate and, therefore, is only recorded if the driver is deceased because of the crash. Roughly 75% (2,762) of deceased drivers receive a blood test.[26] Exhibit 4 depicts trends in deceased drivers who were THC-positive by race/ethnicity. Most THC-positive drivers who are deceased because of the crash are recorded as White (72%). Furthermore, White drivers see the largest increase in the number of THC-positive readings after the first quarter of 2015. Hispanic drivers make up the second-largest share of deceased THC-positive drivers (12%). Due to limited sample sizes, we are not able to explore how traffic fatalities change with cannabis retail access by racial/ethnic group.

Exhibit 4

Quarterly Number of Drivers Involved in Fatal Traffic Accidents THC, by Race/Ethnicity 2008-2019



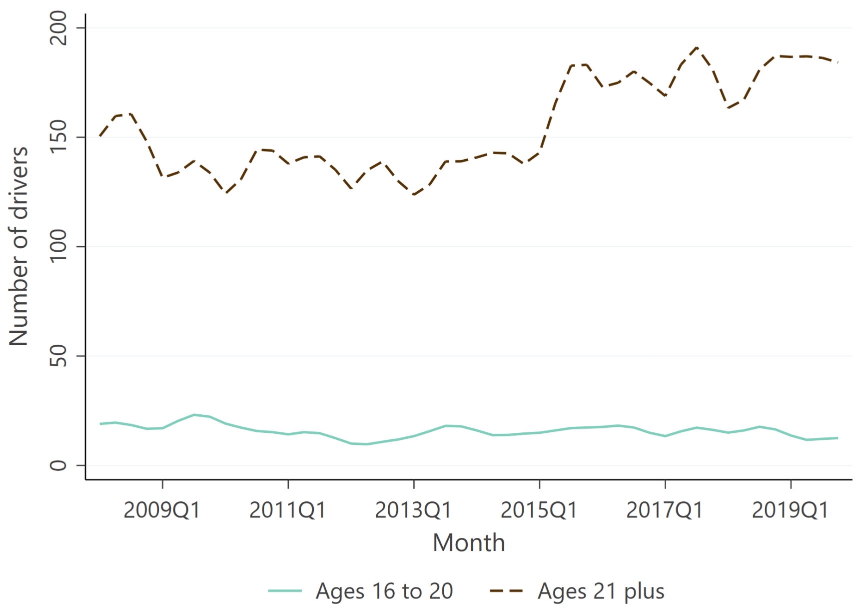
Notes:
Data come from the Coded Fatal Crash (CFC) data files, 2008-2019.
Mutually exclusive racial categories are as follows: non-Hispanic American Indian/Alaska Native, non-Hispanic Asian/Pacific Islander, non-Hispanic Black, non-Hispanic White, and Hispanic.

[26] 99% of deceased drivers have a recorded race/ethnicity.

Additionally, due to the limited sample size, we cannot conduct analyses for youth and young adult drivers ages 16-20. For the remainder of the paper, our sample is restricted to drivers ages 21 and over—this group comprises 90% of drivers involved in a fatal crash (Exhibit 5).

Exhibit 5

Quarterly Number of Drivers Involved in Fatal Traffic Accidents THC, By Age 2008-2019



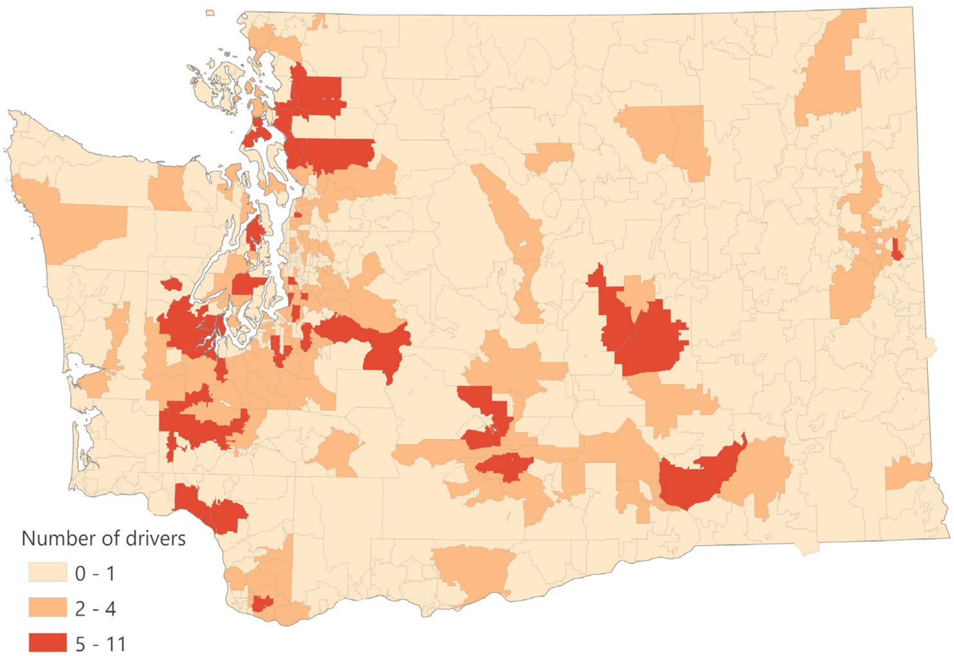
Note:
Data come from the Coded Fatal Crash (CFC) data files, 2008-2019.

There is variation in where fatal traffic collisions occur. Exhibit 6 maps the total number of drivers involved in a crash by ZIP code in 2019.[27] Note we assign drivers to a ZIP code based on the drivers' residential ZIP code, *not* the ZIP code where the collision occurs. We focus on residential ZIP codes because our analysis will focus on access to NMC retailers based on place of residence. Although the prevalence of drivers involved in fatal crashes varies throughout the state, most drivers reside in relatively densely populated urban areas. The prevalence of THC-positive drivers follows a similar geographic pattern but is far less frequent. Due to the limited sample size, we are unable to explore differences in outcomes across regions.

[27] These boundaries are based in the Census 2010 ZIP code tabulation areas (ZCTAs).

Exhibit 6

Number of drivers Involved in a Fatal Traffic Crash in Washington, By Drivers' Residential ZIP Codes 2019



Note:
Data come from the 2019 Coded Fatal Crash (CFC) data files.

Characteristics of Sample

Our analysis will examine how access to licensed cannabis retailers is related to traffic fatalities. Therefore, we will focus on fatal collisions between July 2014, the start of NMC retail sales, and December 2019. Over this period, there were 4,200 drivers involved in a fatal crash, with 2,107 (51%) receiving a blood test. Among drivers who received a blood test, 475 (23%) tested positive for THC, and 1,632 (77%) tested negative. THC status was not tested for 2,093 (49%) drivers.[28] Exhibits 7 and 8 summarize driver and crash characteristics in relation to the presence of THC.

Among drivers for whom THC status is known (Columns 1 and 2 of Exhibit 7), drivers who are THC-positive are more likely to be under the age of 65 (96%) and less likely to be female (18%) than drivers who do not test positive for THC. THC-positive drivers, when compared to THC-negative drivers, are also more likely to drive without a license (21% versus 15%), have previously received a moving traffic violation (61% versus 48%), or register a BAC at or above 0.08 (44% versus 25%).

[28] Roughly 3% of blood-tested drivers yield inconclusive THC test results and are omitted from Exhibits 7 & 8.

Exhibit 7

Driver Characteristics, Fatal Crashes 2014-2019

	THC content known (via blood test)			
	THC-positive	THC-negative	THC unknown	Total
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Driver age (years)	34.39 (14.07)	44.92 (19.06)	45.00 (18.70)	43.76 (18.68)
Age group:				
16-20	0.12 (0.33)	0.08 (0.28)	0.07 (0.26)	0.08 (0.27)
21-65	0.84 (0.37)	0.75 (0.43)	0.77 (0.42)	0.77 (0.42)
65+	0.04 (0.20)	0.17 (0.38)	0.16 (0.37)	0.15 (0.36)
Female driver	0.18 (0.39)	0.25 (0.43)	0.31 (0.46)	0.27 (0.44)
Driver died	0.76 (0.43)	0.74 (0.44)	0.12 (0.33)	0.44 (0.50)
Driver died on impact	0.48 (0.50)	0.46 (0.50)	0.05 (0.21)	0.26 (0.44)
Driver not injured in crash	0.11 (0.31)	0.14 (0.34)	0.52 (0.50)	0.33 (0.47)
Driving without a license	0.21 (0.41)	0.15 (0.35)	0.09 (0.29)	0.13 (0.33)
Driver has previous DUI	0.07 (0.25)	0.07 (0.25)	0.02 (0.15)	0.05 (0.21)
Driver has previous moving traffic violation	0.61 (0.49)	0.48 (0.50)	0.41 (0.49)	0.46 (0.50)
Driver's license and car registration out-of-state	0.06 (0.24)	0.07 (0.26)	0.08 (0.28)	0.08 (0.27)
Driver was only vehicle occupant	0.76 (0.43)	0.77 (0.42)	0.66 (0.47)	0.71 (0.45)
Vehicle type:				
Passenger vehicle	0.78 (0.41)	0.75 (0.43)	0.82 (0.39)	0.79 (0.41)
Motorcycle	0.19 (0.39)	0.18 (0.38)	0.04 (0.20)	0.11 (0.32)
Large truck/bus	0.01 (0.09)	0.06 (0.23)	0.13 (0.34)	0.09 (0.28)
Other	0.02 (0.13)	0.01 (0.11)	0.01 (0.09)	0.01 (0.10)
Other-drug positive	0.33 (0.47)	0.31 (0.46)	0.63 (0.52)	0.32 (0.47)
Driver BAC 0.08 or higher	0.44 (0.50)	0.25 (0.43)	0.36 (0.49)	0.29 (0.46)
Observations	**475**	**1,632**	**2,093**	**4,200**

Note:
Data come from the Coded Fatal Crash (CFC) data files, 2014-2019.

As summarized in Exhibit 8, among crash characteristics, we observe that fatal crashes in which a driver tests THC-positive are more likely to occur at night (5 p.m. to 5 a.m.) compared to fatal crashes that do not have a THC-positive driver (65% versus 49%).

In Exhibits 7 and 8, we observe several marked differences in characteristics between drivers who received a blood test (first two columns) and those who never received a blood test (third column).[29] *This highlights the fact that our analyses do not allow for the generalization of THC prevalence among all drivers involved in fatal crashes but merely the 51% for whom a blood test was conducted and conclusive.*

Exhibit 8

Crash Characteristics, Fatal Crashes 2014-2019

	THC content known (via blood test)			
	THC-positive Mean (SD)	THC-negative Mean (SD)	THC unknown Mean (SD)	Total Mean (SD)
Single-vehicle crash	0.50 (0.50)	0.44 (0.50)	0.29 (0.45)	0.37 (0.48)
Occurred between 5 p.m.-5 a.m.	0.65 (0.48)	0.49 (0.50)	0.47 (0.50)	0.50 (0.50)
Occurred on weekend (Friday-Sunday)	0.49 (0.50)	0.48 (0.50)	0.47 (0.50)	0.47 (0.50)
Weather conditions clear	0.72 (0.45)	0.70 (0.46)	0.67 (0.47)	0.69 (0.46)
Occurred on a state road	0.47 (0.50)	0.54 (0.50)	0.56 (0.50)	0.54 (0.50)
Occurred in urban region	0.58 (0.49)	0.50 (0.50)	0.59 (0.49)	0.55 (0.50)
Observations	**475**	**1,632**	**2,093**	**4,200**

Note:
Data come from the Coded Fatal Crash (CFC) data files, 2014-2019.

[29] Standard t-test difference in means testing across the two groups—those who received a blood test and those who did not receive one—indicates that most differences in driver characteristics are statistically significant at the 5%-level. Results from this analysis are available upon request.

III. Research Design

For this analysis, we examine how changes in access to licensed NMC retailers over time predict changes in the prevalence of annual traffic fatalities in the average ZIP code.[30] The first cannabis sales from a licensed retailer in Washington State occurred in July 2014. By December 2019, the end of our sample period, there were about 463 operational licensed cannabis retailers in the state. Our primary definition of *access* is the average drive time to the nearest operational NMC retailer from a ZIP code.[31] Over our sample period, the statewide average drive time to the nearest retailer is 11.5 minutes.

We estimate a Poisson model to capture the impact of travel time on driver counts. In particular, we estimate the relationship between *the natural log* of the average drive time to the nearest retailer (in minutes) and the number of drivers involved in a fatal traffic collision. We use the natural log of drive time to account for the fact that the impact of a reduction in drive time will differ depending on the initial distance. For example, the impact of a 10-minute reduction in drive time may differ depending on whether we are moving from 60 to 50 minutes versus 15 to 5 minutes. Our models account for relevant time-varying ZIP code demographic and economic characteristics.[32]

In addition to the overall number of drivers involved in a fatal crash, we estimate similar models to examine if changes in retail access relate to changes in the prevalence of drivers who test positive for THC, THC and any alcohol, and a BAC of 0.08 or greater. These analyses allow us to understand potential mechanisms through which retail access can explain changes in overall fatal collisions.[33]

[30] Traffic fatalities are a relatively rare outcome—on average, only 1.05 drivers from a ZIP code are involved in a traffic fatality annually—therefore we examine changes in outcomes at the annual level as opposed to the monthly or quarterly level.

[31] We use 2019 census block-group data to approximate household locations throughout the state. For computational feasibility, we produce a 0.5% population sample of synthetic households to approximate the spatial distribution of household residential locations. The exact location assigned to any synthetic household within a block-group is random assuming a uniform distribution of families within the livable areas of census block-group boundaries—we include census block-group boundaries that are on a tax parcel with a building on it or a military base. The travel time between each household and each operational NMC retailer (within 120 minutes) is then estimated. The synthetic household sample and drive times were generated using ArcGIS Pro.

[32] All models account for annual ZIP code population, racial makeup, unemployment rate, high school and college graduation rates, household rental rates, and median household income. We additionally account for the county-level annual number of active police officers, county-level fixed effects, year fixed effects, and county specific linear time trends. Standard errors are estimated to adjust for clustering at the ZIP-code level.

[33] In comparable analyses of other outcomes (Licensed Cannabis Retail Access and Substance Use Disorder Diagnoses) we also examined the sensitivity of our primary findings to the inclusion of measures of retailer density. Specifically, controlling for distance to the nearest retailer, we measure the impact of the number of NMC retailers nearby (e.g., the average number of retailers within 5 minutes/15 minutes). However, there are very few observations and fatal crashes in ZIP codes with several retailers nearby. Therefore, we cannot confidently and reliably estimate this relationship here.

IV. Results

Total Fatalities

We first examine how the average minimum drive time to the nearest operational licensed NMC retailer relates to the total number of drivers involved in a fatal crash. Here, an increase in the number of drivers necessarily implies an increase in the number of cars involved in fatal crashes. Importantly, a driver's involvement in a fatal crash does not necessarily imply the driver is deceased, just that someone is deceased because of the collision; for example, it could be a passenger, pedestrian, or another driver.

The results from this analysis are presented in Column 1 of Exhibit 9. The estimates in Exhibit 9 are difficult to meaningfully interpret because they tell us about the relationship between the natural log of minimum average drive time and the number of drivers involved in a fatal collision. Therefore, we transform these results such that we approximate the increase in the statewide annual number of drivers involved in fatal crashes for a given change in the average drive time to the nearest retailer. These results are illustrated in Exhibit 10. For example, our results imply that *a 50% reduction in the average drive time to the nearest retailer predicts about 46 more drivers involved in a fatal crash annually in Washington State (a 5.9% increase)*.[34] *Alternatively, a 75% decrease in drive time to the nearest retailer predicts 92 more drivers involved in a fatal crash annually in Washington State (an 11.8% increase).*

Exhibit 9

Drive Time to the Nearest NMC Retailer and Drivers in Fatal Crashes

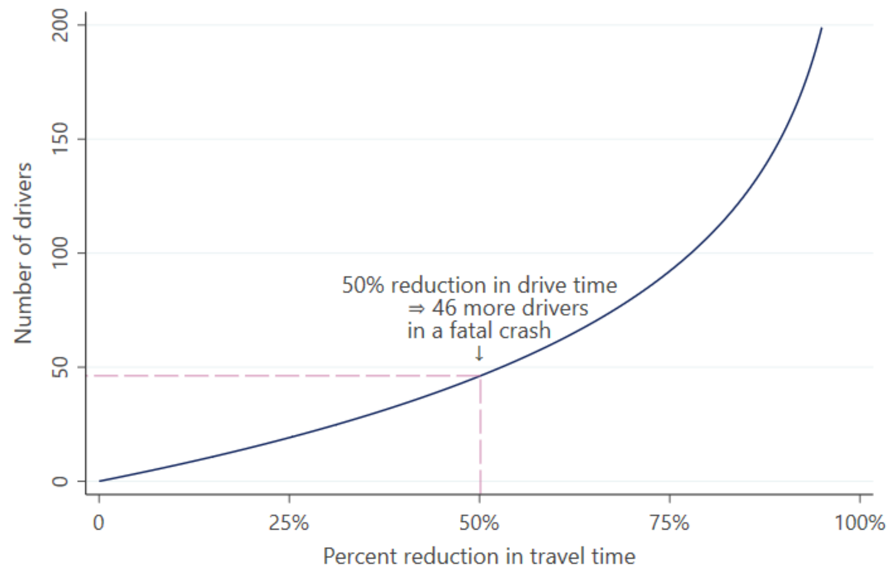
	All drivers (1)	Deceased drivers (2)	No injury drivers (3)
Natural log of minimum drive time to the nearest retailer	-0.1115** (0.0548)	-0.0152 (0.0289)	-0.0415 (0.0256)
Outcome mean	1.360	0.601	0.429
Outcome standard deviation	1.707	0.898	0.798
Observations	**2,703**	**2,703**	**2,703**

Notes:
We report marginal effects from Poisson models.
Each column summarizes estimates from separate regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the ZIP level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level.

[34] This estimate comes from first computing a change in the number of drivers using $\beta_1 * \ln\left(\frac{[100+p\%]}{100}\right) = 0.1115 \times \ln\left(\frac{[100-50]}{100}\right)$. This calculation implies that a 50% reduction (p = -50) in drive time increases the number of drivers involved in fatal crashes by 0.077 in a ZIP code each year. Given that there are 596 ZIP codes in our analysis, that is roughly 0.077 × 596 = 46 more drivers statewide.

Exhibit 10

Travel Time to the Nearest NMC Retailer and Statewide Annual Number of Drivers Involved in a Fatal Collision



Note:
This these estimates plot the following function $\beta_1 * \ln\left(\frac{[100+p\%]}{100}\right) = 0.1115 \times \ln\left(\frac{[100-p\%]}{100}\right)$.

To examine if more proximate NMC retail access relates to collision severity, we assess if changes in the average drive time predict changes in both the number of *driver deaths* resulting from the collision (Exhibit 9, Column 2) and the number of *drivers with no resulting injury* (Exhibit 9, Column 3)—i.e., high-severity and low-severity outcomes, respectively. The results from this analysis indicate there is no significant relationship between average drive time to the nearest retailer and our measures of the severity of injuries sustained.[35]

THC-Positive and Alcohol-Positive Drivers

Our previous analysis examined changes in the prevalence of all drivers involved in a fatal crash. We now examine how NMC retail access predicts changes in the prevalence of THC-positive drivers. These analyses will allow us to better understand the channel through which NMC retail access may predict increases in the overall prevalence of drivers involved in fatal crashes. The results from our examination of THC-positive drivers are presented in Exhibit 11.[36] The estimates presented in Column 1 indicate a significant relationship between NMC retail access and the prevalence of THC-positive drivers (at least 1.0 ng/mL blood content). For interpretation, Exhibit 12 depicts the relationship between percent changes in drive time and corresponding changes in the average number of THC-positive drivers involved in a fatal crash annually statewide. For example, a *50% reduction in average drive time to the nearest retailer predicts 13 more drivers involved in a fatal crash annually who test positive for THC—this corresponds to a 14% increase in the average number of THC-positive drivers.*

[35] In analyses not presented here, we examine if changes in minimum average drive time relate to changes in the number of blood-tested drivers—our results are statistically insignificant.

[36] To account for potential unrelated changes in the prevalence of blood testing, the models estimated for these analyses additionally control for the total number of drivers who received a blood test.

Exhibit 11

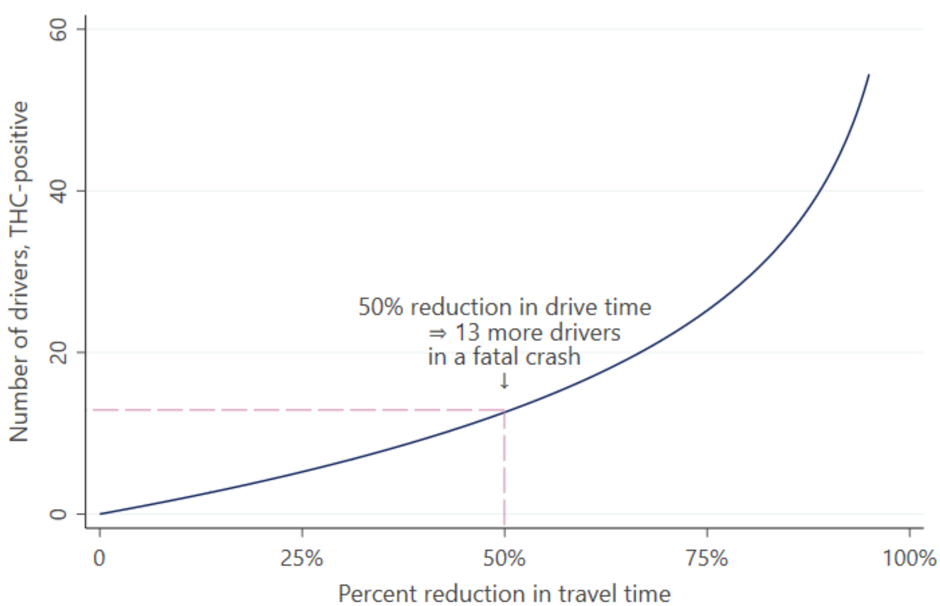
Drive Time and Driver in Fatal Crashes

	Any THC (1)	THC at least 5 ng/mL blood (2)	Any THC and alcohol (3)	BAC at least 0.08 (4)
Natural log of minimum drive time to the nearest retailer	-0.0305**	-0.0142	-0.0111	-0.0149
	(0.0128)	(0.0102)	(0.0104)	(0.0155)
Outcome mean	0.149	0.090	0.085	0.209
Outcome standard deviation	0.411	0.319	0.301	0.485
Observations	**2,703**	**2,703**	**2,703**	**2,703**

Notes:
We report marginal effects from Poisson models.
Each column summarizes estimates from separate regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the ZIP level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level

Exhibit 12

Travel Time to the Nearest NMC Retailer and Annual Number of THC-Positive Drivers Involved in a Fatal Collision



Note:
This these estimates plot the following function $\beta_1 * \ln\left(\frac{[100+p\%]}{100}\right) = 0.0305 \times \ln\left(\frac{[100-p\%]}{100}\right)$.

Importantly, THC may be detected in blood days or weeks after use. Therefore, a THC-positive test does *not* confirm that the driver was impaired at the time of the fatality or had recently used cannabis. However, some studies have suggested that higher THC blood content may better indicate cannabis use shortly before driving.[37] Therefore, we examine the relationship between NMC retail access and drivers with a higher THC concentration of at least 5.0 ng/mL blood content. The estimates summarized in Column 2 of Exhibit 11 indicate a 50% reduction in the average drive time to the nearest retailer relates to a 10% increase in the prevalence of drivers with a THC concentration of at least 5.0 ng/mL. However, given the rarity of the outcome, our estimates are imprecise, making it challenging to detect statistical significance for small or moderate effects.[38]

Evidence has suggested that the risk for collision associated with cannabis in combination with alcohol is greater than the risk for either drug by itself.[39] Therefore, we also examine the relationship between NMC retail access and the number of drivers who test positive for any THC in combination with alcohol. The estimates summarized in Column 3 of Exhibit 11 indicate a 50% reduction in the average drive time to the nearest retailer relates to an 8% increase in the prevalence of drivers who test positive for the presence of both THC and alcohol. Again, given the rarity of the outcome, our estimates are imprecise, making it challenging to detect statistical significance for small or moderate effects.[40]

Last, we examine the relationship between NMC retail access and the prevalence of drivers who test positive for alcohol with a BAC of at least 0.08 (Exhibit 11, Column 4). The estimated result is not statistically significant and relatively small in magnitude.

[37] Bergamaschi, M.M., Karschner, E.L., Goodwin, R.S., Scheidweiler, K.B., Hirvonen, J., Queiroz, R.H., & Huestis, M.A. (2013). Impact of prolonged cannabinoid excretion in chronic daily cannabis smokers' blood on per se drugged driving laws. *Clinical chemistry*, *59*(3), 519-526.
[38] We cannot confidently estimate the relationship between NMC retail access and the prevalence of higher concentrations of THC (e.g., at least 10 ng/mL) due to the rarity with which the outcome occurs; only 3% of drivers in a ZIP-year test positive for a THC concentration of at least 10 ng/mL.
[39] Hartman, R.L., & Huestis, M.A. (2013). Cannabis effects on driving skills. *Clinical chemistry*, *59*(3), 478-492.
[40] We cannot confidently estimate the prevalence of drivers who test positive for THC in combination with other drugs because of the rarity with which we observe this outcome. We do not explore the relationship between retail access and the presence of non-cannabis drugs alone because we are unable to identify specific drug types.

V. Limitations and Discussion

Limitations

There are several limitations to consider when interpreting results.

Primarily, we ultimately cannot establish that our estimated relationship between NMC retail access and traffic fatalities is *caused* by changes in impaired driving behavior. This is because THC may be detected in blood days or weeks after use. Therefore, a THC-positive blood test does not confirm that the driver was impaired or had recently used cannabis at the time of the collision.

Furthermore, since NMC retail licenses are not randomly allocated, the proximity of local retailers may capture systematic differences across ZIP code traffic fatality outcomes unrelated to retail sales and cannabis use. For example, if locales that allow NMC retail sales and a greater number of retailer licenses also tend to have laxer perceptions of traffic safety or lower enforcement, then greater proximity will likely predict more fatalities regardless of actual NMC retail sales and cannabis use.[41]

The generalizability of our results regarding changes in the prevalence of THC-positive or alcohol-impaired drivers is limited by the fact that only 50% of our sample was tested for intoxicants. We ultimately cannot speak to how NMC retail access will predict THC prevalence among all drivers involved in fatal crashes. Furthermore, our study only examines fatal traffic outcomes and cannot speak to how access to NMC retail relates to traffic collisions and traffic safety more broadly. Furthermore, due to limited sample size concerns, we could not examine how NMC retail access relates to other key outcomes, such as drivers with higher THC blood content or drivers who test positive for both THC and other drugs. Last, limited sample sizes also inhibit our ability to examine differences in outcomes across relevant populations (e.g., age or race/ethnicity) and geographical regions (urban/rural).

[41] In analyses not presented here, difference-in-means test results indicate several significant differences in demographic and socio-economic characteristics between ZIP codes with an operational retailer and those without. We ultimately cannot distinguish which ZIP codes simply do not have an operational retailer and which ban sales altogether.

Discussion

Overall, our results suggest that greater proximity to a licensed NMC retailer is related to both a modest increase in the prevalence of total drivers involved in a fatal traffic collision and drivers who test positive for THC. We find no evidence that retail access relates to the prevalence of driver deaths, drivers with a THC content at or above 5ng/mL, drivers who test positive for alcohol alone (BAC at least 0.08), or any amount of alcohol in combination with THC. Ultimately, our findings indicate that in areas with more cannabis use (as measured by easier access to NMC retail), there are marginally more drivers involved in fatal traffic collisions.

This study is part of a larger legislative mandate to examine the relationship between I-502 and public health and safety outcomes. In addition to traffic fatalities, for our third required report, we have evaluated outcomes related to the following:

- reported cannabis and other substance use,
- substance use disorder diagnoses, and
- cannabis-related convictions.

Summaries of these analyses can be found in Initiative 502 and Cannabis-Related Public Health and Safety Outcomes: *Third Required Report.*[42]

[42] Rashid (2023).

Acknowledgments

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