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Technical Report—*Licensed Cannabis Retail Access and Substance Use Disorder Diagnoses*

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 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 health*. Specifically, we were directed to consider the health impacts associated with cannabis use, including diagnoses of cannabis-related substance use disorder (SUD).

In this technical report, we provide a comprehensive description of our evaluation of the relationship between access to licensed non-medical cannabis retailers in Washington and disordered substance use among Medicaid beneficiaries in Washington. Specifically, we investigate if the prevalence of SUD diagnoses responds to increased local access as measured by drive time to the nearest licensed NMC retailer and retail density. Our primary health outcomes include diagnoses of cannabis use disorder (CUD), alcohol use disorder (AUD), and opioid use disorder (OUD).

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, traffic collision outcomes, and criminal justice outcomes.

In Section I, we describe how cannabis use and NMC legalization relate to substance use and cannabis-related healthcare utilization 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 describe the limitations of our analysis and discuss our findings.

Suggested citation: Rashid, A., & Adams, N. (2023). *Technical report—Licensed cannabis retail access and substance use disorder* (Document Number 23-09-3205). Olympia: Washington State Institute for Public Policy.

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[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

Effective December 2012, I-502 legalized the possession, use, and commercial sales of non-medical cannabis for people ages 21 and older. The first commercial sales of licensed non-medical cannabis (NMC) started in July 2014. A critical concern relates to how NMC legalization may change cannabis use behavior and lead to increases in cannabis-related adverse health outcomes, including substance use and mental and physical symptoms. There is further concern that NMC laws may produce spillovers that lead to increases in youth cannabis use and subsequent adverse health outcomes.

Legalization and Cannabis Use Disorder (CUD)

Rates of cannabis use disorder and cannabis-related hospitalization have increased in the U.S. over the last two decades, particularly in states with legal medical or recreational cannabis.[5] Several studies have found an association between the passage of NMC laws and increases in adult CUD diagnoses, CUD-related emergency department (ED) encounters, CUD-related hospitalization, and symptoms of cannabis hyperemesis syndrome.[6] Evidence is more mixed across studies examining CUD outcomes for youth, with some finding an adverse relationship between legalization and CUD outcomes and others finding no significant relationship.[7] Studies have also shown increases in pediatric cannabis poisonings in the years after legalization.[8] Notably, despite increases in CUD diagnoses and related ED encounters, some studies have found that cannabis-related treatment admission rates have generally declined among adults and adolescents.[9] However, it is unclear whether observed declines in treatment admissions were due to actual clinical treatment needs or a decline in treatment-seeking behavior due to reduced perceived risk towards cannabis use and the need for treatment.[10]

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[5] Roehler, D.R., Hoots, B.E., Holland, K.M., Baldwin, G.T., & Vivolo-Kantor, A.M. (2022). Trends and characteristics of cannabis-associated emergency department visits in the United States, 2006–2018. *Drug and Alcohol Dependence*, *232*, 109288 and Hasin, D.S., Sarvet, A.L., Cerdá, M., Keyes, K.M., Stohl, M., Galea, S., & Wall, M.M. (2017). US adult illicit cannabis use, cannabis use disorder, and medical marijuana laws: 1991-1992 to 2012-2013. *JAMA Psychiatry*, *74*(6), 579-588.

[6] Cannabinoid hyperemesis syndrome (CHS) is a condition in which a patient experiences cyclical nausea, vomiting, and abdominal pain after using cannabis. Vignault, C., Massé, A., Gouron, D., Quintin, J., Asli, K.D., & Semaan, W. (2021). The potential impact of recreational cannabis legalization on the prevalence of cannabis use disorder and psychotic disorders: A retrospective observational study. *The Canadian Journal of Psychiatry*, *66*(12), 1069-1076; Cerdá, M., Mauro, C., Hamilton, A., Levy, N.S., Santaella-Tenorio, J., Hasin, D., . . . Martins, S.S. (2020). Association between recreational marijuana legalization in the United States and changes in marijuana use and cannabis use disorder from 2008 to 2016. *JAMA Psychiatry*, *77*(2), 165-171; Delling, F.N., Vittinghoff, E., Dewland, T.A., Pletcher, M.J., Olgin, J.E., Nah, G., . . . Marcus, G.M. (2019). Does cannabis legalisation change healthcare utilisation? A population-based study using the healthcare cost and utilisation project in Colorado, USA. *BMJ Open*, *9*(5), e027432; Wang, G.S., Davies, S.D., Halmo, L.S., Sass, A., & Mistry, R.D. (2018). Impact of marijuana legalization in Colorado on adolescent emergency and urgent care visits. *Journal of Adolescent Health*, *63*(2), 239-241; and Dilley, J.A., Fiala, S.C., Hendrickson, R.G., Giffin, S., Everson, E.M., Hedberg, K. (2019). *Acute cannabis-related adverse events after starts of retail sales in Oregon*.

[7] Montgomery, B.W., Roberts, M.H., Margerison, C.E., & Anthony, J.C. (2022). Estimating the effects of legalizing recreational cannabis on newly incident cannabis use. *PloS one*, *17*(7), e0271720 and Wang et al. (2018).

[8] Wang, G.S., Hoyte, C., Roosevelt, G., & Heard, K. (2019). The continued impact of marijuana legalization on unintentional pediatric exposures in Colorado. *Clinical Pediatrics*, *58*(1), 114-116.

[9] Rhee, T.G., & Rosenheck, R.A. (2022). Admissions to substance use treatment facilities for cannabis use disorder, 2000–2017: Does legalization matter? *The American Journal on Addictions*, *31*(5), 423-432 and Mennis, J., & Stahler, G.J. (2020). Adolescent treatment admissions for marijuana following recreational legalization in Colorado and Washington. *Drug and Alcohol Dependence*, *210*, 107960.

[10] Mennis et al. (2020).

Legalization and Other Substance Use

Studies have also examined the relationship between cannabis policy and other substance use—particularly opioid use. As opioid mortality has increased substantially over the past two decades, there has been increased interest in the therapeutic potential of cannabinoids as both an alternative to opioid analgesics for the treatment of chronic pain and an adjunct or alternative treatment for opioid use disorder (OUD).[11] Alternatively, there is concern that cannabis could serve as a "gateway drug" to arguably more harmful substances such as opioids. Most of the literature has specifically focused on the relationship between NMC laws and opioid prescribing behavior. Some studies using Medicare and Medicaid data have found a decline in prescribing measures in the years following legalization.[12] However, there is concern that these studies may not adequately consider coincident private-sector or public-sector strategies and policies aimed at reducing inappropriate opioid prescribing behavior. These alternative factors, which are difficult to account for in observational studies, may explain some of the decreases in prescribing behavior observed in studies using claims or self-reported data.

Furthermore, a recent meta-analysis found that, on average, prior cannabis use was a significant predictor of initiating opioid use or transitioning to an OUD.[13] However, subgroup analyses indicated that this impact was not uniform across individual characteristics. For example, one study found that when cannabis users with CUD were excluded from the study, there was no longer a greater likelihood of transitioning to OUD.[14] This may indicate that an understanding of the *severity* of use is necessary when examining the relationship between cannabis use and opioid use.

A few studies have examined the relationship between NMC legalization and alcohol use. Using self-reported data, recent studies have found evidence that NMC legalization is associated with a slight increase in the probability of reported alcohol use, with some studies suggesting that legalization predicts increases in reported binge drinking among older adults.[15]

While these studies provide insight into the relationship between cannabis use and related health outcomes, they also demonstrate the difficulty in establishing the population-level causal impacts of legalization on substance use and healthcare utilization.

[11] Smart, R., & Pacula, R.L. (2019). Early evidence of the impact of cannabis legalization on cannabis use, cannabis use disorder, and the use of other substances: Findings from state policy evaluations. *The American Journal of Drug and Alcohol Abuse*, *45*(6), 644-663 and Wiese, B., & Wilson-Poe, A.R. (2018). Emerging evidence for cannabis' role in opioid use disorder. *Cannabis and cannabinoid research*, *3*(1), 179-189.

[12] Smart, & Pacula (2019)

[13] Wilson, J., Mills, K., Freeman, T.P., Sunderland, M., Visontay, R., & Marel, C. (2022). Weeding out the truth: a systematic review and meta-analysis on the transition from cannabis use to opioid use and opioid use disorders, abuse or dependence. *Addiction*, *117*(2), 284-298.

[14] Wilson et al. (2022).

[15] Gonçalves, P.D., Bruzelius, E., Levy, N.S., Segura, L.E., Livne, O., Gutkind, S., . . . Martins, S.S. (2023). Recreational cannabis legislation and binge drinking in US adolescents and adults. *International Journal of Drug Policy*, *118*, 104085 and Macha, V., Abouk, R., & Drake, C. (2022). Association of recreational cannabis legalization with alcohol use among adults in the US, 2010 to 2019. In *JAMA Health Forum, 3*(11), e224069-e224069).

NMC Retail Market and Cannabis Use

Emerging literature has focused on the impact of the commercialization of cannabis on the types of products available and the ways it can be consumed. This is important because studies have indicated that in addition to the frequency of use, how one uses cannabis (e.g., smoke, eat, or vaporize) and the potency and dosage of the product also contribute to the magnitude of intoxication and potential health impacts.[16] Consumable cannabis product potency and variety have evolved under legal protections and increased market competition.[17] For example, cannabis concentrates, documented to have delta-9-tetrahydrocannabinol (THC) concentrations greater than 70%, were the fastest-growing share of the NMC retail cannabis market in the years immediately following legalization in Washington.[18]

This evidence has indicated that the legalization of commercial NMC retail has changed the landscape of cannabis products and methods of use, which may subsequently impact cannabis use behavior and the severity of use. An expanding legal retail market also increases access to legal cannabis; more proximate retailers translate to a lower travel time and overall cost of cannabis consumption. Accordingly, emerging cannabis literature has specifically focused on the health impacts of legal NMC retail. Some studies have found that the advent of retail operations is a larger predictor of cannabis-related adverse health events than the act of legalization itself.[19] Other studies have found higher average rates of reported cannabis use and cannabis-related healthcare utilization in counties with operational retailers compared to counties with no retailers.[20]

Current Study

This study expands upon the existing literature by examining the relationship between licensed NMC retail access and substance use disorder diagnoses among individuals enrolled in Medicaid in Washington State. In particular, we examine how retailer access predicts the probability of receiving a diagnosis for disordered cannabis use, alcohol use, or opioid use. We also examine the prevalence of comorbidity between CUD and these other substance use disorders. This study primarily measures NMC retail access as drive time to the nearest retailer.[21]

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[16] Budney, A.J., & Borodovsky, J.T. (2017). The potential impact of cannabis legalization on the development of cannabis use disorders. *Preventive Medicine*, *104*, 31-36.
[17] Smart et al. (2019) and Carlini, B.H., Garrett, S.B., & Harwick, R.M. (2017). *Beyond joints and brownies: Marijuana concentrates in the legal landscape of WA State.*
[18] Smart, R., Caulkins, J.P., Kilmer, B., Davenport, S., & Midgette, G. (2017). Variation in cannabis potency and prices in a newly legal market: evidence from 30 million cannabis sales in Washington State. *Addiction*, *112*(12), 2167-2177.
[19] Walker, M., Carpino, M., Lightfoot, D., Rossi, E., Tang, M., Mann, R., . . . Cusimano, M.D. (2023). The effect of recreational cannabis legalization and commercialization on substance use, mental health, and injury: a systematic review. *Public Health*, *221*, 87-96 and Myran, D.T., Roberts, R., Pugliese, M., Taljaard, M., Tanuseputro, P., & Pacula, R.L. (2022). Changes in emergency department visits for cannabis hyperemesis syndrome following recreational cannabis legalization and subsequent commercialization in Ontario, Canada. *JAMA Network Open*, *5*(9), e2231937-e2231937.
Wang, G.S., Buttorff, C., Wilks, A., Schwam, D., Tung, G., & Pacula, R.L. (2022). Impact of cannabis legalization on healthcare utilization for psychosis and schizophrenia in Colorado. *International Journal of Drug Policy*, *104*, 103685.
[20] Manthey, J., Jacobsen, B., Hayer, T., Kalke, J., López-Pelayo, H., Pons-Cabrera, M.T., ... & Rosenkranz, M. (2023). The impact of legal cannabis availability on cannabis use and health outcomes: a systematic review. *International Journal of Drug Policy*, *116*, 104039 and Wang, G.S., Buttorff, C., Wilks, A., Schwam, D., Tung, G., & Pacula, R.L. (2022). Impact of cannabis legalization on healthcare utilization for psychosis and schizophrenia in Colorado. *International Journal of Drug Policy*, *104*, 103685.
[21] In secondary analyses, we additionally define access through measures of retailer density.

As previously discussed, we expect greater access to predict greater cannabis use, which may impact subsequent CUD and other substance use. 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.[22] 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.[23] 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.*[24]

Given that proximity to an NMC retailer predicts greater reported cannabis use, in this study, we examine if the prevalence of diagnosed substance use disorders changes among Medicaid enrollees residing in census tracts (i.e., neighborhoods) with increasingly proximate access to a retailer. Specifically, we address the following three questions:

> *Question 1: Is a shorter average drive time to the nearest retailer in a census tract related to the probability of receiving a CUD, AUD, or OUD diagnosis?*
>
> *Question 2: Is a shorter average drive time to the nearest retailer in a census tract related to the probability of co-occurrence of both CUD and AUD diagnoses or CUD and OUD diagnoses?*
>
> *Question 3: In addition to shorter drive times, does the number of nearby licensed NMC retailers relate to the probability of a CUD, AUD, or OUD diagnosis?*

[22] 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.

[23] 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.

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

II. Data

This study uses person-level administrative monthly records of relevant health care received by Medicaid enrollees in Washington State.[25] Specifically, we have information about the population of individuals ages 12 and older who are enrolled in Medicaid at any time between January 1, 2010, and December 31, 2019.[26]

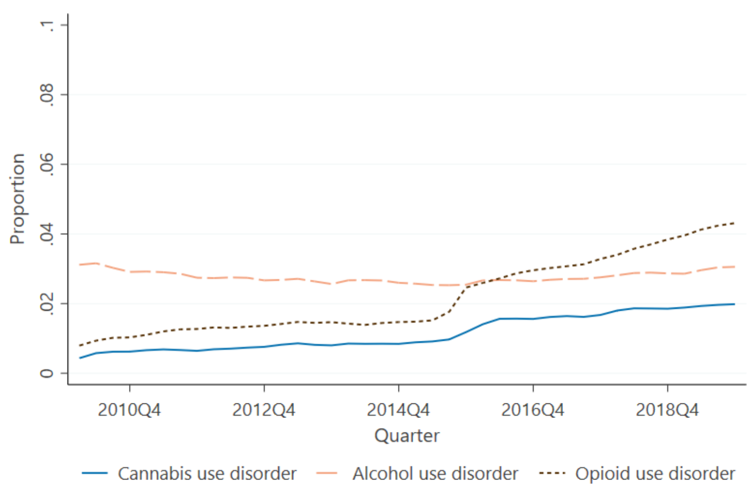
Our analyses related to NMC retail access will only examine health outcomes after the advent of licensed NMC operations in July 2014. However, we use data on all Medicaid enrollees from January 1, 2010, through December 31, 2019, to examine statewide trends in substance use diagnoses. In particular, we first describe trends in outcomes starting in 2010. Second, we describe the demographic and health characteristics of Medicaid enrollees during the study period of 2014-2019. This study primarily focuses on outcomes for adults ages 21 and older.

Outcomes

Our primary outcome measures indicate if a beneficiary has had any Medicaid claim or encounter records, including a CUD, AUD, or OUD diagnosis code. These diagnostic categories can arise from a number of healthcare uses, including a hospitalization, an office visit, an emergency department visit, or a stay at a SUD residential treatment facility.[27] Exhibit 1 depicts the average quarterly proportion of enrollees with (at least one) substance use disorder diagnosis between 2010 and 2019. During this period, roughly 900,000 individuals ages 21 and older were enrolled in Medicaid each quarter.

Exhibit 1

Proportion of Medicaid Enrollees with Substance Use Disorder Diagnosis, Ages 21 and Older—Quarterly Averages between 2010-2019



Note:
Data come from administrative Medicaid enrollee records between 2010-2019.

[25] Washington State Medicaid claims data are provided by Department of Social and Health Services, Research and Data Analysis Division from its Integrated Client Databases (ICDB). ICDB contains administrative data from several state data systems, including the ProviderOne Medicaid data system and the Behavioral Health Data System (BHDS). See Mancuso & Huber (2021) at for more details.
[26] The study population includes individuals who receive full Medicaid benefits and partial benefits.
[27] Our outcome variables do not necessarily capture disease onset or initial diagnosis.

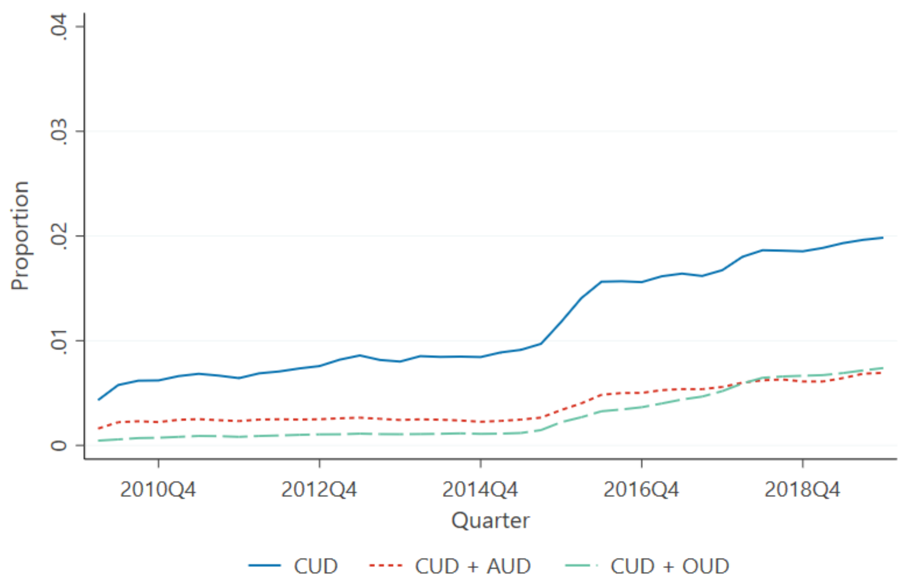
Among enrollees, the proportion of quarterly CUD and OUD diagnoses steadily increased over time, with a notable jump in 2015—the prevalence of OUD diagnoses has generally grown at a relatively faster pace.[28]

Over this period, roughly 1.2% of the sample received a CUD diagnosis, and 2.5% were diagnosed with OUD. Over this same period, the proportion of AUD diagnoses has remained relatively stable at an average of about 2.8% of claimants per quarter.

We also examine co-occurring diagnoses between CUD and other substance use disorders. Exhibit 2 depicts the average quarterly proportion of claimants diagnosed with both CUD and AUD and the proportion of claimants diagnosed with both CUD and OUD in the same quarter. On average, about 50% of quarterly CUD claims are co-occurring with AUD *or* OUD, and roughly 10% are occurring with AUD *and* OUD. Rates of both co-occurring CUD conditions were relatively constant until the third quarter of 2015 when rates began to trend upwards. By the end of the sample, the average quarterly rate of CUD and co-occurring AUD diagnoses or CUD and co-occurring OUD diagnoses are roughly the same at about 0.007.

Exhibit 2

Proportion of Medicaid Enrollees with Cannabis use and Other Co-Diagnoses, Ages 21 and Older—Quarterly Averages between 2010-2019



Note:
Data come from administrative Medicaid enrollee records between 2010-2019.

[28] In October 2015, the switch from ICD 9 to ICD 10 could have impacted the number of people diagnosed with SUD, however, we cannot verify if this contributed to the increase observed around the fourth quarter of 2015 in Exhibit 1. In robustness analyses, not presented here, we demonstrate that our main results (shown in Exhibits 4 & 6) are robust to the exclusion of claims data before the switch in October 2015.

Sample Characteristics

Our analysis examines how access to licensed cannabis retailers is related to SUD diagnoses. Therefore, we focus on claims between July 2014, the start of NMC retail sales, and December 2019. Exhibit 3 summarizes the demographic characteristics of Medicaid enrollees ages 21 and older over this period. Column 1 describes the characteristics of enrollees who are ever diagnosed with CUD (over the entire sample period), Column 2 describes enrollees who are never diagnosed with CUD, and Column 3 describes the entire sample.

A greater proportion of claimants who have ever received a CUD diagnosis are Native American (0.14), Black (0.13), or White (0.63) compared to those who have never been diagnosed with CUD (respectively, 0.06, 0.09, 0.59). Enrollees diagnosed with CUD are also less likely to be female (0.47 versus 0.59) and less likely to be over the age of 64 (0.02 versus 0.13).[29]

Exhibit 3

Characteristics of Medicaid Enrollees Ages 21 and Older, July 2014-December 2019

	Ever cannabis use disorder	Never cannabis use disorder	Total
	Mean (SD)	Mean (SD)	mean (SD)
Race/ethnicity:			
Native American	0.14 (0.35)	0.06 (0.25)	0.07 (0.26)
Asian	0.03 (0.17)	0.10 (0.29)	0.09 (0.28)
Black	0.13 (0.34)	0.09 (0.29)	0.09 (0.29)
Hispanic	0.11 (0.31)	0.15 (0.36)	0.15 (0.35)
Native Hawaiian or other Pacific Islander	0.02 (0.16)	0.04 (0.20)	0.04 (0.19)
White	0.63 (0.48)	0.59 (0.49)	0.59 (0.49)
Female	0.47 (0.50)	0.59 (0.49)	0.58 (0.49)
Age:			
21-25	0.14 (0.34)	0.13 (0.33)	0.13 (0.33)
26-64	0.84 (0.37)	0.74 (0.44)	0.75 (0.43)
65 plus	0.02 (0.15)	0.13 (0.34)	0.12 (0.32)
Urban residence	0.86 (0.35)	0.85 (0.35)	0.85 (0.35)
Observations	2,375,858	17,850,904	20,226,762

Notes:
Data come from administrative Medicaid enrollee records between 2010-2019.

[29] The population above 64 is most likely to be receiving Medicare benefits, and therefore Medicaid data do not provide a representative description of their behavioral health outcomes and health care utilization.

III. Research Design

For this analysis, we examine if changes in access to licensed NMC retailers over time predict changes in the probability of receiving a CUD, AUD, or OUD diagnosis annually in the average census tract.[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 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 census tract.[31] Over our sample period, the statewide average drive time to the nearest retailer is 11.5 minutes.

We estimate an OLS regression model to capture the impact of drive time on SUD. In particular, the relationship between *the natural log* of the average drive time to the nearest retailer (in minutes) and the probability of disordered substance use. We use the natural log of drive time to account for the impact of a reduction in drive time, which 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 available individual-level demographic characteristics and time-varying census tract demographic and economic characteristics.[32]

In secondary sensitivity analyses, we examine if the number of nearby retailers relates to outcomes separately from drive time.

[30] These SUD diagnoses are relatively rare—for example, on average, only 0.8% of the sample is diagnosed with CUD in each quarter—therefore we examine changes in outcomes at the annual 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] We account for race/ethnicity, sex, age, and the reason for Medicaid eligibility. We also account for annual census tract population, racial makeup, unemployment rate, high school and college graduation rates, median household income, and the proportion of the population that work in a major metropolitan city. We additionally account for county-level fixed effects and year fixed effects. Standard errors are estimated to adjust for clustering at the census tract level.

IV. Results

Substance Use Disorder and Travel Time—Enrollees Ages 21 and Older

We first examine how the average minimum drive time to the nearest operational retailer relates to the probability of receiving a CUD diagnosis among Medicaid enrollees ages 21 and older. Over the study period, roughly 3.1% of our sample have received a CUD diagnosis in a given year.[33] The results of this analysis are presented in Column 1 of Exhibit 4. The estimates in Exhibit 4 are difficult to interpret meaningfully because they tell us about the relationship between the natural log of minimum average drive time and the probability of CUD diagnosis. Therefore, we transform these results to approximate the percent increase in the probability of CUD diagnosis for a given change in the average drive time to the nearest retailer in a given year. These results are illustrated in Exhibit 5. For example, our results imply that *a 50% reduction in drive time to the nearest retailer is associated with a 2.3% higher likelihood of CUD diagnosis that year (roughly 850 more claimants with a CUD diagnosis)*.[34]

The results summarized in Columns 2 and 3 of Exhibit 4 imply that *a 50% reduction in the average drive time to the nearest retailer implies a 1.8% higher likelihood of an AUD diagnosis and a 3.3% higher likelihood of an OUD diagnosis in a given year.* Our results indicate that access predicts a slightly larger increase in OUD versus CUD. We ultimately cannot determine why this is the case. It is possible that CUD increases are higher than we observe, but individuals are less likely to seek treatment for or be diagnosed with CUD than OUD.[35] Furthermore, SUD diagnoses resulting from emergency health care utilization are more likely to occur for opioid misuse compared to cannabis misuse. To understand this further, information about diagnosing behavior, treatment-seeking behavior, and SUD-related healthcare encounters would be required. In addition, our study period coincides with increases in opioid misuse in Washington State (especially in rural regions). Therefore, if other factors increasing opioid misuse over this period disproportionately impact neighborhoods that simultaneously experienced large increases in NMC retail, this could alternatively explain estimated increases in OUD.[36]

More generally, it is important to note that we cannot account for changes in health care provision, access, or SUD treatment. Therefore, if relevant health care or treatment access systematically increases with retail access, this could alternatively explain increases in any of our SUD diagnoses (especially AUD and OUD) independent of cannabis use. Importantly, our outcome measures do not directly capture healthcare *need*. Rather, they are measures of healthcare *utilization* that are influenced by need and healthcare access, types of healthcare providers, and attitudes toward treatment.

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[33] Our analysis sample drops enrollees who are missing demographic or geographic residential information.

[34] This estimate comes from first computing a change in the probability of CUD $\beta_1 * \ln\left(\frac{[100+p\%]}{100}\right) = 0.0010 \times \ln\left(\frac{[100-50]}{100}\right)$. This calculation implies that a 50% reduction (p = -50) in drive time increases the probability of CUD by 0.07 percentage points. Given that the average probability of past-year CUD is 0.031, this result implies a 2.3% increase in the likelihood.

[35] Williams, A.R., & Hill, K.P. (2019). Cannabis and the current state of treatment for cannabis use disorder. *FOCUS, A Journal of the American Psychiatric Association*, *17*(2), 98-103 and Hasin, D.S., Kerridge, B.T., Saha, T.D., Huang, B., Pickering, R., Smith, S. M., . . . Grant, B.F. (2016). Prevalence and correlates of DSM-5 cannabis use disorder, 2012-2013: Findings from the National Epidemiologic Survey on Alcohol and Related Conditions–III. *American Journal of Psychiatry*, *173*(6), 588-599.

[36] University of Washington. Opioid trends across Washington State—Data notes.

Exhibit 4

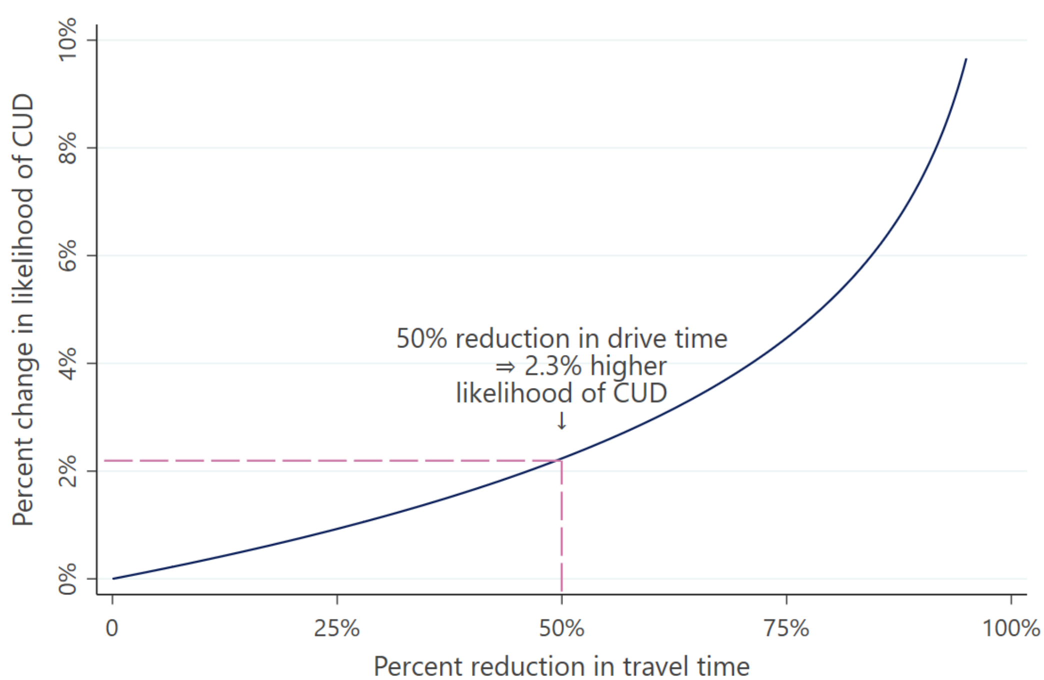
Drive Time to the Nearest NMC Retailer and Substance Use Disorder Diagnoses—Medicaid Enrollees Ages 21 and Older

	Past-year CUD diagnosis	Past-year AUD diagnosis	Past-year OUD diagnosis
Natural log of minimum drive time to the nearest retailer	-0.0010*** (0.0003)	-0.0014*** (0.0005)	-0.0022*** (0.0006)
Observations	7,296,976	7,296,976	7,296,976
Outcome mean	0.031	0.049	0.045
Standard deviation	0.174	0.216	0.207

Notes:
Each column summarizes estimates from separate OLS regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the census tract level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level.

Exhibit 5

Travel Time to the Nearest NMC Retailer and Probability of Cannabis Use Disorder (CUD)



Note:
This these estimates plot the following function $\beta_1 * \ln\left(\frac{[100+p\%]}{100}\right) = 0.0010 \times \ln\left(\frac{[100-p\%]}{100}\right)$.

Overall, our findings suggest that less travel time to an NMC retailer predicts a modest increase in the probability of a CUD, AUD, or OUD diagnosis among Medicaid enrollees ages 21 and older. These findings suggest that greater access is related to not only higher general cannabis use but possibly more severe cannabis use. Our findings suggest a complementary relationship between cannabis use and alcohol or opioid misuse. These findings are supported by select studies which have linked cannabis use to binge drinking and OUD. Our findings are further supported by studies highlighting that it is likely disordered cannabis use, not general use, that relates to a higher likelihood of opioid misuse. However, further information about diagnostic and treatment behaviors and alternative health care-related policies and interventions is required to conclusively determine the causal relationship between cannabis use and other substance misuses.

Co-occurring CUD and SUD Diagnoses

We next examine the relationship between access and the probability of co-occurring CUD and AUD diagnoses and co-occurring CUD and OUD diagnoses in a given year. These analyses allow us to examine better the relationship between CUD and other disordered substance use. The results from these analyses are presented in Exhibit 6. Our results imply that *a 50% reduction in the average drive time to the nearest retailer relates to a 2% higher likelihood of co-occurring CUD and AUD diagnoses and a 3.8% higher likelihood of co-occurring CUD and OUD diagnoses (annually)*. These findings further suggest that disordered cannabis use is associated with a higher likelihood of AUD and OUD. Importantly, these results do not establish that CUD *causes* AUD or OUD, only that co-occurring diagnoses are more probable in neighborhoods with greater retail access.

Exhibit 6

Drive Time to the Nearest NMC Retailer and Co-occurring Substance Use Disorder Diagnoses—Ages 21 and Older

	Co-occurring CUD and AUD	Co-occurring CUD and OUD
Natural log of minimum drive time to the nearest retailer	-0.0004** (0.0001)	-0.0005*** (0.0001)
Observations	7,296,976	7,296,976
Mean	0.010	0.008
Standard deviation	0.099	0.091

Notes:
Each column summarizes estimates from separate OLS regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the census tract level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level.

Subgroup Analyses

In analyses not presented here, we examine if access to NMC retail differs across individual characteristics. Here, we summarize notable findings.

Region of Residence. We replicate our primary analyses (Exhibit 4) separately for the sample of enrollees in urban neighborhoods and those in rural neighborhoods. Roughly 26% of our sample reside in a rural-designated census tract. The minimum average drive time in rural neighborhoods is 23 minutes versus an average of about nine minutes in urban neighborhoods. We find that the magnitude of the relationship between retail access and CUD or AUD is comparable across regions of residence. However, the relationship estimated between greater access and a greater likelihood of OUD diagnosis is driven by enrollees who reside in rural neighborhoods. Specifically, *a 50% reduction in the average drive time to the nearest retailer in rural neighborhoods relates to a 4.8% higher likelihood of an OUD diagnosis.*

Demographic Characteristics. We examine results across racial/ethnic categories: Black, White, Native American, Asian, and Native Hawaiian or other Pacific Islander.[37] Notably, access predicts a higher likelihood of CUD across all populations except for Native American enrollees, even though Native Americans have the highest average rate of CUD (at 5.9% annually relative to a sample average of 3.1%).[38] The relationship between NMC access and CUD is highest among Black enrollees, who have a 4.2% average annual rate of CUD over the sample period. Specifically, *a 50% reduction in the average drive time to the nearest retailer among Black enrollees implies a 4% higher likelihood of a CUD diagnosis.* The relationship between NMC access and CUD is lowest among White enrollees, who have a 3.3% average annual rate of CUD. Specifically, *among White enrollees, a 50% reduction in the average drive time to the nearest retailer implies a 1.8% higher likelihood of a CUD diagnosis.*

Last, we examine results across sex. The relationship between access and the probability of an annual occurrence of CUD/AUD/OUD diagnosis is comparable across male and female enrollees.

Substance Use Disorder and Travel Time—Enrollees Ages 12-20

We briefly explore the relationship between drive time to the nearest retailer and the occurrence of a SUD diagnosis in a given year among enrollees ages 12-20. Relative to legal-aged adults, CUD diagnoses are less common among younger age groups: about 1.5% of youth ages 12-17 are diagnosed with CUD annually, about 2.6% of young adults ages 18-20 are diagnosed with CUD annually, and about 3.1% of adults ages 21 and older are diagnosed with CUD annually. Exhibit 7 examines outcomes for enrollees ages 12-17, separate from enrollees ages 18-20. The estimates summarized in Column 1 of Panel A indicate that greater access does not significantly correlate with changes in the probability of CUD for enrollees ages 18-20. However, the estimates summarized in Column 1 of Panel B imply that greater access predicts a higher likelihood of CUD among adolescents ages 12-17. Specifically, *among adolescent enrollees ages 12-17, a 50% reduction in drivetime relates to a 4.7% higher likelihood of a CUD diagnosis*. This evidence suggests that a potential unintended consequence of legal cannabis retail is more severe youth cannabis use.

For other substances, our estimates suggest that among adolescents ages 12-17, greater access to an NMC retailer does not relate to the likelihood of AUD or OUD diagnoses in a given year. However, among young adults ages 18-20, shorter travel time to an NMC retailer does predict a higher likelihood of OUD (about a 7% increase in likelihood for a 50% decrease in drive time).

[37] Individuals can identify as multiple racial/ethnic categories.

[38] Our access measures only use information about licensed NMC retailers; therefore, NMC retailers operating on Tribal land are not included in our study.

Exhibit 7

Drive Time to the Nearest NMC Retailer and Substance Use Disorder Diagnoses—Medicaid Enrollees Ages 12-20

	Past-year CUD diagnosis	Past-year AUD diagnosis	Past-year OUD diagnosis
Panel A: Ages 12-17			
Natural log of minimum drive time to the nearest retailer	-0.0011*** (0.0003)	-0.0001 (0.0003)	-0.0001* (0.0001)
Observations	1,727,761	1,727,761	1,727,761
Mean	0.015	0.009	0.001
Standard deviation	0.122	0.092	0.035
Panel B: Ages 18-20			
Natural log of minimum drive time to the nearest retailer	-0.0003 (0.0005)	-0.0004 (0.0005)	-0.0007** (0.0003)
Observations	704,598	704,598	704,598
Mean	0.026	0.016	0.007
Standard deviation	0.160	0.124	0.082

Notes:
Each column summarizes estimates from separate OLS regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the census tract level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level.

NMC Retail Density

Last, we examine the sensitivity of our primary estimates (shown in Exhibit 4) to the inclusion of retail density measures. We conduct these analyses for the population of enrollees ages 21 and older. Density is important to consider because a greater concentration of local retailers will increase customer competition through advertising, product pricing, or product selection, which could ultimately drive greater cannabis use. Here, we define density in three ways: the (census tract) average number of retailers within 5 minutes, 10 minutes, and 15 minutes.[39] Exhibit 8 reports estimates from three separate models, each incorporating a measure of retail density. For each model, we report the coefficient estimates for the minimum average drive time and the average number of nearby retailers.

The results summarized in Panels A and B indicate that when we account for the number of retailers within five minutes or 10 minutes, the relationship between average drivetime and the likelihood of a CUD/AUD/OUD diagnosis occurring annually is now small and no longer significant. This is not surprising because, in neighborhoods with multiple retailers located nearby (within 5-10 minutes), we would not expect marginal changes in drive time to greatly impact perceived travel costs. In this case, the number of nearby retailers predicts a higher likelihood of past-year CUD, AUD, or OUD. *Our estimates imply that one more operational NMC retailer within 5 minutes predicts a 4.2% higher likelihood of past-year CUD, and one more retailer within 10 minutes predicts a 1.3% higher likelihood of CUD*.

[39] We use measures of density like Ambrose et al. (2021).

We would expect that as the drive time radius increases, the marginal impact of density would decrease. In fact, the estimates summarized in Panel C imply that if we expand the radius to the number of retailers within 15 minutes, the relationship between density and our measures of SUD essentially drops to zero. In Panel C, we observe that the average drive time to the nearest retailer is the significant predictor of our SUD measures (the results in Panel C are comparable to the primary findings reported in Exhibit 4).[40]

Our results indicate that density is more predictive of a CUD diagnosis than travel time in neighborhoods with multiple retailers within very close proximity. This is likely because in relatively more competitive NMC retail markets, cannabis products may be more potent, advertised more heavily, or consumers may face lower prices. These factors could explain more frequent and severe cannabis use.[41] Ultimately, only 10% of our sample reside in a census tract with an average of more than one operational retailer located within 5 minutes; further examination of the characteristics of these unique neighborhoods and their local policies is required to understand better the relationship between retail density and cannabis-related health outcomes.

[40] The findings reported in Panel C were robust to alternative measures of density including the number of retailers within 30 minutes and 45 minutes.

[41] Note, since NMC retail licenses are not randomly allocated across the state, there may be other relevant characteristics of locales that allow for multiple license allotments that are not captured by our model but separately impact cannabis use. However, since we are exploiting variation within county over time it is unlikely that our results are solely driven by omitted considerations.

Exhibit 8

NMC Retailer Density and Substance Use Disorder Diagnoses—Medicaid Enrollees Ages 21 and Older

	Past-year CUD diagnosis	Past-year AUD diagnosis	Past-year OUD diagnosis
Panel A: Within 5			
Natural log of minimum drive time to the nearest retailer	0.0004	0.0008	-0.0002
	(0.0006)	(0.0012)	(0.0012)
Number of retailers within 5 minutes	0.0013***	0.0021**	0.0018**
	(0.0004)	(0.0009)	(0.0009)
Panel B: Within 10			
Natural log of minimum drive time to the nearest retailer	-0.0003	0.0000	-0.0010
	(0.0005)	(0.0007)	(0.0008)
Number of retailers within 10 minutes	0.0004***	0.0007***	0.0006**
	(0.0001)	(0.0002)	(0.0002)
Panel C: Within 15			
Natural log of minimum drive time to the nearest retailer	-0.0010**	-0.0010*	-0.0019***
	(0.0004)	(0.0006)	(0.0006)
Number of retailers within 15 minutes	0.0000	0.0002*	0.0001
	(0.0001)	(0.0001)	(0.0001)
Observations	7,296,976	7,296,976	7,296,976
Outcome mean	0.031	0.049	0.045
Standard deviation	0.174	0.216	0.207

Notes:
Each column summarizes estimates from separate OLS regressions.
Each model includes the full set of control variables and adjusts standard errors for clustering at the census tract level.
***Significant at the 0.001-level, **significant at the 0.05-level, and *significant at the 0.10-level.

V. Limitations and Discussion

Limitations

There are several limitations to consider when interpreting results.

Importantly, retailers are not randomly located throughout the state, and there is considerable variation in travel time and density of NMC retailers across the state. The proximity and density of local retailers may capture systematic differences across census-tract-level health outcomes unrelated to retail sales and cannabis use. Furthermore, we cannot account for local policies or prevention efforts that both systematically coincide with NMC retailer openings and impact substance use outcomes. Last, we cannot account for changes to neighborhood-level healthcare access which occur over the study sample period.[42]

Our study only describes the relationship between NMC retail access and outcomes for the subset of the Washington population enrolled in Medicaid. Our findings cannot be used to draw conclusions pertaining to the overall population. For that, we would require access to more representative claims data across all types of insurance providers in the state.

Our study does not provide evidence for a definitive mechanism between NMC retail access and CUD or NMC access and other substance use disorders. To comprehensively understand how greater access to more retailers impacts the severity of cannabis use and other drugs, we need more information about the prices, potency, and types of products used. Additionally, we need to understand better how legalization has impacted cannabis-related treatment-seeking behavior, related healthcare utilization, and the perceived health risks of cannabis use. Last, our findings suggest that the relationship between access and SUD outcomes is not uniform across all individuals. How NMC retail access predicts cannabis use and cannabis-related health outcomes likely differs across community-level characteristics, such as urbanicity, healthcare access, racial makeup, and measures of economic well-being.

Future research will work to understand further where and who is most impacted by access to retail. In subsequent reports, we aim to incorporate more cannabis-related health outcomes and healthcare utilization measures. For example, we may explore the relationship between retail access and cannabis-related hospitalization and treatment. Importantly, emerging literature has explored the relationship between cannabis use and psychiatric reactions, with some demonstrating a link between chronic and/or severe cannabis use and the onset of psychiatric disorders such as psychosis. Therefore, future reports will also explore the relationship between NMC retail access, mental health outcomes, and related healthcare utilization.

[42] Washington State opted to expand Medicaid Coverage under the Affordable Care Act in 2014 which added thousands of new enrollees. In alternative analyses, we test the sensitivity of our primary findings to the exclusion of enrollees who were only made eligible through the 2014 expansion—results are robust to this sample exclusion.

Discussion

Overall, our findings suggest that less travel time to an NMC retailer predicts a small increase in the probability that a claim within a given year includes the diagnosis code for CUD among our study sample of Medicaid enrollees ages 21 and older and enrollees ages 12-17. These findings suggest that greater access relates to not only higher general cannabis use but also more CUD-related care and potentially more severe cannabis use among adult and adolescent claimants.

Increased access to NMC retailers predicts 1) higher probabilities of AUD and OUD diagnoses and 2) higher probabilities of co-occurring diagnoses of CUD and AUD/OUD. These findings may suggest a complementary relationship between cannabis use and alcohol or opioid misuse. However, we ultimately cannot determine if cannabis use serves as a "gateway" to other substance use or if those who misuse cannabis are more likely to misuse other substances regardless of cannabis use.

Last, we find that in neighborhoods with multiple retailers located in proximity (within 5 or 10 minutes), an increase in the number of retailers predicts higher likelihoods of CUD, AUD, and OUD. In these high-density neighborhoods, changes in the average travel time to the nearest retailer are an inconsequential predictor of health outcomes.

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 SUD diagnoses among Medicaid claimants, for our third required report, we have evaluated outcomes related to the following:

- reported cannabis and other substance use,
- traffic fatalities, 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.*[43]

[43] Rashid (2023).

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