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Association Between Non-Medical Cannabis Legalization and Alcohol Sales: Quasi-Experimental Evidence from Canada

Running head: Beer and Spirit Sales After Cannabis Legalization

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ABSTRACT

Background: There is increasing interest in understanding the impact of non-medical cannabis legalization on use of other substances, especially alcohol. Evidence on whether cannabis is a substitute or complement for alcohol is both mixed and limited. This study provides the first quasi-experimental evidence on the impact of Canada's legalization of non-medical cannabis on beer and spirits sales.

Methods: We used the interrupted time series design and monthly data on beer sales between January 2012 and February 2020 and spirits sales between January 2016 and February 2020 across Canada to investigate changes in beer and spirits sales following Canada's cannabis legalization in October 2018. We examined changes in total sales, nationally and in individual provinces, as well as changes in sales of bottled, canned and kegged beer.

Results: Canada-wide beer sales fell by 96 hectoliters per 100,000 population ($p=0.011$) immediately after non-medical cannabis legalization and by 4 hectoliters per 100,000 population ($p>0.05$) each month thereafter for an average monthly reduction of 136 hectoliters per 100,000 population ($p<0.001$) post-legalization. However, the legalization was associated with no change in spirits sales. Beer sales reduced in all provinces except the Atlantic provinces. By beer type, the legalization was associated with declines in sales of canned and kegged beer but there was no reduction in sales of bottled beer.

Conclusions: Non-medical cannabis legalization was associated with a decline in beer sales in Canada, suggesting that consumers may be substituting non-medical cannabis for beer. However, there was no change in spirits sales following the legalization.

INTRODUCTION

Canada legalized non-medical cannabis use in October 2018, allowing sales of only dried cannabis, fresh cannabis, cannabis oil, cannabis plants, and cannabis seeds (Government of Canada, 2023). In October 2019, edible cannabis, cannabis extracts, and cannabis topicals (Government of

Canada, 2022) were also legalized. The legalization led to increased cannabis use as early as in the first year after legalization. The prevalence of cannabis use in Canada increased from 14.9% in 2018 (before legalization) to 16.8% in 2019 (after legalization) (Statistics Canada, 2020). Although retail cannabis market was not mature in all provinces during the early stages of the legalization, people could still access cannabis through other alternative sources including online purchases, sharing of cannabis among adults, and cannabis cultivation (which became legal after legalization) as well as through existing illegal stores (for example, over 380 illegal stores existed in Ontario at the time of cannabis legalization (Mahamad et al., 2020)).

The legalization of non-medical cannabis raises questions about its impacts on the use of other substances, especially alcohol. On the one hand, cannabis use might lead to higher alcohol use in individuals, particularly those with greater sensation-seeking behaviors (Linden-Carmichael et al., 2019). Co-use of cannabis and alcohol has been shown to intensify health harms than individual use of these substances, including greater risk of impaired driving, psychiatric disorders, injury and self-harm (Subbaraman and Kerr, 2015; Yurasek et al., 2017). On the other hand, alcohol use might decline if individuals substitute non-medical cannabis for alcohol. While some evidence suggests that alcohol dependence poses greater health risks than cannabis dependence (Hall, 2017; Thayer et al., 2017), cannabis is associated with poor mental health and neurocognitive functioning, increased risk of motor vehicle accidents and risk of cardiovascular, respiratory and other systemic diseases (Fischer et al., 2022; Matheson and Le Foll, 2020). From public health and health policy perspectives, it is critical to understand the effects of cannabis legalization on alcohol use.

Existing evidence on the impact of cannabis use on alcohol use is inconclusive. Several studies have investigated the association between the consumption of alcohol and cannabis with survey data. These studies, however, face the challenge of controlling for individual level factors that affect the use of both substances. Thus, it is perhaps not surprising that some of these studies found that individuals use cannabis and alcohol complementarily (i.e., these substances are used together) (Pacula, 1998; Williams and Mahmoudi, 2004) whereas others found that these substances function as substitutes (i.e., they are used in lieu of each other) (Chaloupka and Laixuthai, 1997; Crost and Guerrero, 2012; Subbaraman, 2016). A few studies addressed this question using the onset of cannabis legalization, which is a plausibly exogenous source of variation in cannabis use

and modelled the attendant effects on alcohol use. These studies, which have focused only on the United States (US), also found mixed results (Alley et al., 2020; Calvert and Erickson, 2021; Kerr et al., 2018, 2017; Subbaraman and Kerr, 2020; Veligati et al., 2020). In particular, Calvert et al. examined the effects on cannabis legalization in three US states on purchases of different types of alcohol. They found that purchases of alcohol (in particular, wine) declined after recreational cannabis was legalized in Colorado. Meanwhile, purchases of spirits increased in Washington but decreased in Oregon after cannabis legalization (Calvert and Erickson, 2021). This uncertainty warrants further research on how legalization of non-medical cannabis affects alcohol consumption.

Findings from the US may also not be generalizable to Canada for several reasons. Only a handful of US states legalized non-medical cannabis, opening the possibility that cannabis was transported across state borders. Such cross-state contamination may have influenced findings of studies that relied on geographical variation in legalization status to identify the effects on alcohol use. By contrast, all ten provinces of Canada legalized non-medical cannabis at once. There also exist differences in drinking culture, alcohol tax rates and other alcohol policy regulations between Canada and the US. For instance, while the minimum legal drinking age in the US is 21, it is 18 or 19 in Canada (depending on province) (Gallup Inc, 2002). Further, health warnings on alcohol products are mandated in the US, but there is no such requirement in Canada (Code of Federal Regulations, 2016).

Although Canada instituted legalization at the federal level, provisions of the legalization such as cannabis possession limits, rules around personal cultivation, minimum legal age, distribution and pricing were under provincial jurisdiction. A key difference concerned the ownership of cannabis retail stores. Four provinces had government-run retail cannabis stores (Nova Scotia, New Brunswick, Prince Edward Island and Quebec) while five provinces (Saskatchewan, Ontario, Manitoba, Alberta and Newfoundland and Labrador) allowed cannabis sales through private stores, and only one province (British Columbia) opted for a mix of public and private stores (Myran et al., 2019). Private stores have longer hours of operations than government-run stores, which might affect ease of cannabis access (Myran et al., 2019). Another difference related to the availability and location of physical retail stores. Compared with other provinces, provinces such as Ontario, Quebec and British Columbia had relatively few physical stores at the time of

legalization although Ontario and British Columbia had a large number of illegal retailers (Myran et al., 2019). In addition, most provinces prohibited sales of cannabis in and around liquor stores and schools while Nova Scotia allowed cannabis sales inside liquor stores (The Globe and Mail, 2018).

Using a quasi-experimental design and time-series data, this study aims to assess the impact of non-medical cannabis legalization on beer and spirits sales in Canada. We consider not only nation-wide changes in total beer and spirit sales but also sales in individual Canadian provinces and by beer type.

METHODS

Study design

An Interrupted Time Series (ITS) design (Kontopantelis et al., 2015) was used to test the association between Canada's non-medical cannabis legalization and beer and spirits sales. Given the differences in price, composition and consumption contexts between beer and spirits, and thus the possible differential impacts of the legalization, we examined these effects separately for both alcohol types. The onset of legalization can influence sales immediately (an immediate effect) and/or over time (a lagged effect) as individuals gradually adjust behaviors. The ITS analysis can capture both of these possible effects.

Study outcome, data source and study period

Our outcomes of interest were beer and spirits sales. We studied beer sales in Canada and its breakdown by province and by beer type (bottled, canned and kegged). Data on monthly beer and spirit sales were obtained from Beer Canada and Spirits Canada, respectively (Beer Canada, 2023; Spirits Canada, 2023). The data from Beer Canada capture the unit sales of both domestic and imported beer sold in Canada by Beer Canada's members, accounting for approximately 90% of total beer sales in Canada (Beer Canada, 2023); the remaining 10% of sales is from small breweries that are not part of Beer Canada. The data from Spirits Canada covers all retail sales of spirits (whisky, rum, gin, tequila, liqueurs, and vodka) through each of the provincial liquor control boards. Ready-to-drink cocktails were not included (Spirits Canada, 2023).

Data on beer sales were available from January 2012 while those for spirit sales were available from January 2016. As alcohol use patterns changed during the COVID-19 pandemic (Thompson et al., 2021), our analysis covered the period up to February 2020 to avoid potential confounding effects of the pandemic. Thus, we analyzed beer sales from January 2012 to February 2020 and spirits sales from January 2016 to February 2020.

Statistical analysis

The ITS analysis of the cannabis legalization can be implemented by way of a segmented linear regression of the following form:

$$Y_t = \beta_0 + \beta_1 \text{Time trend}_t + \beta_2 \text{Legalization}_t + \beta_3 \text{Time trend} \times \text{Legalization}_t + \beta_4 X_t + \varepsilon_t \quad (1)$$

where Y_t is the outcome variable (beer sales and spirit sales, measured in hectoliters per 100,000 population) in month t ; Time trend_t is the linear time trend; Legalization_t is a dummy variable equal to 1 for the post-legalization period (October 2018 to February 2020), and 0 otherwise; $\text{Time trend} \times \text{Legalization}_t$ captures the number of months post-legalization. β_2 and β_3 are the parameters of primary interest: β_2 estimates the change in the level of outcome variable immediately following legalization while β_3 estimates the change in slope following legalization, compared with the counterfactual (Nguyen and Grootendorst, 2015). In addition, we included a set of controls, represented by X_t . These controls included the monthly consumer price index (CPI) for alcoholic beverages (to capture industry-wide trends, particularly tax hikes and consequent inflationary trends in prices of alcohol over time), and annual Canada-wide unemployment rates (to capture changes in nation-wide economic climate over time). Data on unemployment rates and consumer prices of alcoholic beverages were obtained from Statistics Canada (Statistics Canada, 2018a, 2018b).

As the beer and spirits sales exhibited strong seasonal patterns, these data were de-seasonalized using X-13 ARIMA, the US Census Bureau's seasonal adjustment method to remove these seasonal patterns and identify the underlying trend (US Census Bureau, 2023). Specifically, this method removed the seasonal patterns using linear regression models that described the time series of retail sales with covariance described by autoregressive moving average errors (US Census Bureau, 2023). This method for seasonal adjustment was particularly suitable for our study, as it

allowed adjustment for both seasonality and the December holiday effects observed in our sales data.

Equation (1) was estimated using ordinary least squares. As a Cumby-Huizinga test (Baum and Schaffer, 2013) indicated autocorrelation in de-seasonalized sales, heteroscedasticity and autocorrelation-consistent Newey-West standard errors were used. All estimations were done using STATA 16 (StataCorp, 2021).

We conducted several analyses to examine the robustness of our results. We re-estimated equation (1) excluding control for CPI. Next, we replaced the CPI for alcoholic beverages with two CPIs specific to beer/spirits, namely, CPI for beer/spirits sold in retail outlets and CPI for beer/spirits served in licensed establishments (such as restaurants and bars). Finally, to rule out potential confounding effects of the legalization of cannabis edibles in October 2019, we re-estimated equation (1) for the time period before October 2019.

Subgroup analyses by province and beer type

We re-estimated equation (1) individually for each province to examine differences in the effects of the legalization across provinces (our analyses excluded the territories). As sales in the four Atlantic provinces (Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick) were relatively smaller than in other provinces, our analysis examined the total sales across these four provinces.

Additionally, we examined possible differential effects of the legalization for each of the three beer types, namely, bottled, canned and kegged beer. The type of container in which beer is consumed affects the freshness, taste, ease of transportability and the drinking experience (Betancur et al., 2020). Furthermore, kegged beer is commonly consumed in bars and restaurants while canned and bottled beer are more commonly used at home. Given that there are restrictions on the use of smoked or vaped cannabis inside bars and restaurants and bars face legal liabilities from serving individuals already impaired from cannabis use, we suspect that individuals who use cannabis would likely consume cannabis at home or in cannabis lounges than at bars. Thus, we would expect a smaller reduction in kegged beer than in canned/bottled beer after recreational cannabis legalization.

RESULTS

Descriptive analysis

Figure 1 presents unadjusted and seasonally adjusted beer and spirits sales. Panel A shows that unadjusted total sales exhibited a distinct seasonal pattern, both for beer and spirits. During each year, sales were the lowest in January, increased during the first half of the year with peak sales during the summer months of June-August, and declined until November. There was a spike in sales in December, likely because of the holiday season. In Panel B, the de-seasonalized data are much smoother, suggesting that the seasonal fluctuations and December holiday effects were appropriately adjusted for by the X-13 ARIMA seasonal adjustment procedure. There was an overall declining trend in beer sales which may be attributable to various factors such as rising alcohol taxes, changing demographics and growing popularity of craft beer over time (Brewers Journal, 2023; CTV News, 2023, 2016). Meanwhile, the trend in spirits sales was relatively flat. Notably, after October 2018, the rate of decline in beer sales accelerated slightly but the trend in spirits sales remained unchanged.

Figures 2 and 3 show de-seasonalized beer and spirits sales by province. After legalization, there was a marked acceleration in decline in beer sales in the four Western provinces: Manitoba, Saskatchewan, Alberta and British Columbia. Meanwhile, trends in spirits sales were largely unchanged in all provinces after the legalization, except for a slight downward trend observed in Saskatchewan.

By beer type, bottled beer sales followed a declining trend while canned beer sales displayed an increasing trend (Figure 4). However, the increase in canned beer sales slowed down after October 2018. Meanwhile, kegged beer did not exhibit positive or negative monotonic trends before October 2018 but displayed a declining trend between October 2018 and February 2020.

While these figures are suggestive of a decline in beer sales and no change in spirits sales after non-medical cannabis was legalized, they are only unconditional trends that might mask potential confounders. In the next section, we turn to regression analyses to estimate changes in beer and spirits sales after legalization while controlling for potential confounders.

Regression results

In Table 1, we present the regression results with Canada-wide beer and spirits sales as the outcome. Column 1 shows the results of the main segmented regression while columns 2-5 report the results from sensitivity analyses. As shown in Panel A, non-medical cannabis legalization was associated with an immediate decline in beer sales of 96 hectoliters per 100,000 population ($p=0.011$), followed by a decline of 4 hectoliters per 100,000 population ($p>0.05$) in each month thereafter, for an average monthly decline of 136 hectoliters per 100,000 population ($p<0.001$) in the post-legalization period up to February 2020. These results are shown graphically in Figure 5. The magnitude of both the immediate and lagged declines were similar to that in the base case even when we excluded CPI or used CPI for beer purchased in stores or beer served in licensed establishments (columns 2-4). Restricting the time period of analysis to September 2019, the immediate decline in sales was slightly smaller but the lagged decline was larger with the overall average monthly decline very similar to that in the base case analysis (137 hectoliters per 100,000 population; $p<0.001$; column 6). This analysis therefore suggests that the observed decline in the base case analysis was unlikely to be driven by the legalization of cannabis edibles.

Panel B shows that the legalization was associated with no change in spirits sales. The coefficients for both the immediate and lagged changes were small in magnitude and not statistically significant. These results continued to hold when we excluded CPI or used alternative CPI and considered only the time period before the legalization of cannabis edibles.

Table 2 shows changes in beer and spirits sales for each province after legalization. Immediately after legalization, there were large and statistically significant declines in beer sales in Manitoba (123 hectoliters per 100,000 population; $p=0.006$) and Ontario (112 hectoliters per 100,000 population; $p=0.029$). Sales in Manitoba continued to decline significantly during the post-legalization period (12 hectoliters per 100,000 population per month; $p=0.011$). Meanwhile, the immediate impacts of cannabis legalization on beer sales were not statistically significant for Quebec, Saskatchewan, Alberta and British Columbia, but sales declined by 6-37 hectoliters per 100,000 population per month ($p<0.05$). Overall, the four Western provinces (British Columbia, Alberta, Manitoba and Saskatchewan) saw the largest reductions in average monthly beer sales which ranged between 228 and 505 hectoliters per 100,000 population over the post-legalization study period ($p<0.001$). There was no significant immediate or lagged impact of cannabis legalization on beer sales in the Atlantic provinces.

The legalization was not associated with statistically significant, immediate changes in spirits sales in any province, although Saskatchewan saw a gradual decline of 8 hectoliters per 100,000 population per month ($p=0.009$).

We report the regression results by beer type in Table 3. There was an immediate decline in sales of canned beer after legalization (87 hectoliters per 100,000 population; $p=0.002$) which was followed by further declines of 5 hectoliters per 100,000 population per month ($p=0.019$). While the immediate decline in kegged beer sales was small and imprecisely estimated, there were statistically significant lagged declines of 2 hectoliters per 100,000 population ($p=0.001$) in each month after legalization. Meanwhile, there was a small but statistically significant lagged increase in sales of bottled beer (3 hectoliters per 100,000 population per month; $p=0.021$).

DISCUSSION

This study provides the first quasi-experimental evidence on changes in the sales of beer and spirits following the legalization of non-medical cannabis in Canada. We obtained three notable findings. First, Canada-wide beer sales dropped after the legalization, but there was no change in spirits sales. Second, the reductions in beer sales were seen in all except the Atlantic provinces with the four Western provinces experiencing relatively larger declines than the Central provinces. Third, the legalization was associated with a decline in canned and kegged beer sales, but we found no reduction in sales of bottled beer.

Although the magnitude of decline in beer sales appears to be modest, it is economically meaningful. Compared with the total beer sales in September 2018 (before the legalization) of 4,842 hectoliters per 100,000 population, the average monthly decline of 136 hectoliters per 100,000 population by February 2020. represents a 2.8% decline in sales. The magnitude of this effect can be appreciated by comparing it with effects of beer prices on beer consumption. Price elasticity of beer consumption has been estimated to be -0.17 (Wagenaar et al., 2009), meaning that a 10% increase in beer price would lead to a 1.7% decline in demand for beer. Assuming that beer sales reflect beer consumption, the 2.8% decline in beer sales following the legalization is equivalent to an effect of a 16% increase in beer prices.

We found a reduction in beer sales but no change in spirits sales associated with the legalization. In Canada, over 40% of alcohol consumption occurs during weekdays with older adults

particularly using alcohol as a means to unwind on a regular basis (instead of reserving it only for social occasions) (National Post, 2015). Furthermore, 65% of consumption occurs alongside an everyday meal, while watching a game or during after work relaxation (National Post, 2015). Given that beer is generally less expensive and has lower alcohol content than spirits, beer may be preferred in these situations. At the same time, cannabis users report that they prefer to consume alcohol in public events while using cannabis at home “with their partners watching television” (Canadian Centre on Substance Use and Addiction, 2022). These patterns of use explain why beer may be more likely to be substituted with cannabis than spirits.

The effects of legalization on beer sales also varied across provinces. Regional preferences for different alcohol types as well as differences in cannabis retail sales models across provinces can explain these differences. For instance, the Atlantic provinces have a much stronger preference for beer than other alcohol types compared with other provinces (Paradis et al., 2010). These preferences can explain why we did not observe a reduction in beer sales associated with cannabis legalization in these provinces. Meanwhile, easier access to cannabis through private retail stores or a mix of public and private stores in the Western provinces (Myran et al., 2019) may explain the large declines in beer sales observed in these provinces.

While canned and kegged beer sales declined after legalization, we found no reduction in sales of bottled beer. One possible explanation is that cans may be preferred to bottle in the context of individual consumption at home due to the increasing popularity and availability of cans as well as the better taste and drinking experience that they offer (CBC News, 2022; HuffPost, 2012). Thus, as cannabis substitutes at-home beer consumption, we find a substitution of cannabis for canned beer but not for bottled beer.

Our findings may have policy implications. Previous studies have showed that the non-medical cannabis legalization was associated with an increase in cannabis initiation among both youth (Nguyen et al., 2022) and adults (Farrelly et al., 2023). Our study found that the legalization was associated with a reduction in beer sales. Taken together, these findings suggest that the recreational cannabis legalization was associated with a potential substitution away from beer towards cannabis. While increased use of cannabis is not necessarily harmless and further research is needed to understand the health effects of the switch from alcohol to cannabis, the reduction in beer sales associated with the non-medical cannabis legalization suggests that individuals are

likely not using alcohol and cannabis concurrently. However, given the psychotic and neurocognitive effects of cannabis use as well as its adverse impacts on adolescents' brain development, it will be increasingly important to tightly regulate the cannabis market to prevent unauthorized sales to minors and to ensure adherence to packaging, labelling and promotional requirements (Government of Canada Department of Justice, 2018).

Our study has some limitations. First, due to data availability, we could not examine changes in other types of alcohol such as wine, cider and pre-mixed cocktails. However, given that beer and spirits together constitute over 60% of total alcohol sales (Government of Canada, 2023b), we expect that changes in beer and spirits sales after legalization likely led to changes in total alcohol consumption. This is likely as substitution to wine, cider, and pre-mixed cocktails, if any, is likely to be small given that beer is preferred by men, youth and low-income individuals for both price and cultural reasons (Gallup Inc, 2019, 2016). Second, we could not explicitly model the effects of legalization of cannabis edibles and drinkables in October 2019 to avoid potential confounding effects of the COVID-19 pandemic. We could also not examine the effects specifically on sales of cannabis infused alcoholic beverages or the co-use of cannabis and alcohol. These will be important areas for further research. Furthermore, our analysis considered only the period prior to the COVID-19 pandemic. Previous studies have shown that alcohol sales increased during the COVID-19 pandemic driven by both pandemic-related stressors and expanded off-premise alcohol delivery and hours of operation of liquor stores (MacKillop et al., 2021; Myran et al., 2021; Stockwell et al., 2022). As long-term post-pandemic data become available, it will be interesting to examine the combined influence of the recreational cannabis legalization and the pandemic. Third, our analysis was unable to shed light on heterogeneity in the effects of the legalization on alcohol use across different demographic groups. It is possible that alcohol consumption changed differently within certain subgroups by gender and age. Future studies using individual-level data should examine this heterogeneity. Finally, estimates from the ITS model might be biased if there was an intervention or a shock that also affected alcohol consumption at the same time as the non-medical cannabis legalization. Between 2018 and 2019, various policy changes occurred including changes in interprovincial shipping/importation requirements, beer compositional standards which placed restrictions on residual sugar content and imposed labelling requirements, restrictions on alcohol content in flavored purified beverages and mandatory alcohol screening for drivers. However, there is no reason to expect that changes in interprovincial shipping/importation

requirements would reduce sales in all major provinces. Moreover, our finding of immediate decline in beer sales after cannabis legalization -- and before the implementation of other policy changes -- suggests that our effects are unlikely to be driven by these changes.

CONCLUSION

We found that non-medical cannabis legalization was associated with an immediate decline in beer sales. Furthermore, beer sales continued to decline in the post-legalization period, suggesting that individuals are moving away from beer towards legal cannabis. These declines in beer sales were most pronounced in the four Western provinces. Meanwhile, we found no change in spirits sales following the legalization.

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Table 1: Effects of legalization on beer and spirit sales, Canada wide

	(1)	(2)	(3)	(4)	(5)
	Base case	Unemployment rate only	CPI store	CPI licensed	Pre-cannabis edible legalization
<i>Beer sales</i>					
Legalization	-95.92* (36.83)	-81.27** (26.78)	-81.71** (27.56)	-88.76** (27.63)	-68.18* (31.72)
Time trend x Legalization	-4.45 (2.77)	-5.72* (2.29)	-3.12 (2.96)	-6.75** (2.10)	-10.61** (2.78)
Time trend	-9.26 (5.18)	-4.60** (1.15)	-8.09** (2.42)	-7.49** (2.60)	-9.10 (5.25)
N	98	98	98	98	93
Average monthly effect of legalization	- 135.94** (24.06)	-132.78** (21.26)	-109.79** (25.60)	-149.55** (28.27)	-137.13** (22.82)
<i>Spirits sales</i>					
Legalization	-6.56 (5.82)	-6.09 (5.80)	-5.88 (5.78)	-4.32 (6.62)	-8.87 (5.80)
Time trend x Legalization	-0.37 (0.88)	-0.54 (0.84)	-0.48 (0.80)	-0.73 (1.15)	0.11 (0.90)
Time trend	0.47 (1.08)	0.85 (0.76)	0.56 (0.60)	1.24 (1.44)	0.54 (1.19)
N	50	50	50	50	45
Average monthly effect of legalization	-9.90 (8.85)	-10.92 (8.64)	-10.16 (8.06)	-10.89 (8.51)	-8.14 (7.74)

Note: CPI: Consumer Price Index. Data are monthly beer sales from Beer Canada for the period January 2012 to February 2020 and monthly spirits sales from Spirits Canada for the period January 2016 to February 2020. Results in column (5) are obtained using data before cannabis edibles were legalized, i.e., till September 2019. Beer and spirit sales (in hectoliters per 100,000 population) are seasonally adjusted using X-13 ARIMA seasonal adjustment (US Census Bureau, 2023). All models include a linear time trend, indicator for post-legalization period (October 2018 onwards), interactions between post-legalization period and time trend, and controls for consumer price index for alcoholic beverages and unemployment rate. All models are estimated using linear regressions. Newey West standard errors are estimated with maximum lags determined by Cumby-Huizinga test. Average monthly effect is calculated as 'Level change + (Trend change * 9)' where 9 is the average number of post-legalization months during our study period. Significance level: * $p < 0.05$, ** $p < 0.01$

Table 2: Effects of legalization on beer and spirits sales, by province

	Atlantic provinc es	Quebec	Ontario	Manito ba	Saskatchew an	Alberta	British Columbi a
Beer sales							
Legalizatio n	-98.68	-23.44	- 111.79 *	- 122.61* *	-172.84	-86.84	-116.10
	(74.37)	(32.89)	(50.29)	(43.56)	(88.84)	(63.37)	(70.87)
Time trend x Legalizatio n	-2.44	-5.58*	-0.27	-11.73*	-36.91**	- 22.90**	-20.09**
	(4.56)	(2.52)	(4.17)	(4.53)	(7.30)	(3.73)	(5.61)
Time trend	0.30	-6.80*	-9.64	-4.48	4.83	8.87	6.37**
	(6.01)	(3.33)	(5.78)	(3.34)	(5.87)	(5.84)	(1.54)
N	98	98	98	98	98	98	98
Average monthly effect of legalization	- 120.65	-73.65*	-114.22	- 228.18* *	-505.07**	- 292.94* *	- 296.94**
	(71.19)	(28.87)	(58.34)	(57.42)	(77.80)	(61.32)	(68.17)
Spirit sales							
Legalizatio n	-3.29	-2.33	-6.94	-1.08	30.52	0.28	-5.42
	(4.46)	(5.39)	(7.31)	(4.01)	(17.31)	(19.21)	(14.62)
Time trend xLegalizati on	0.54	0.20	-0.38	0.22	-7.92**	1.86	0.30
	(0.36)	(0.34)	(0.64)	(0.40)	(2.90)	(2.08)	(1.38)
Time trend	-0.87	0.14	0.71	-0.21	3.28	-1.74	-2.11
	(0.64)	(0.37)	(0.77)	(0.25)	(2.48)	(2.01)	(2.30)
N	50	50	50	50	50	50	50
Average monthly effect of legalization	1.58	-0.52	-10.38	0.94	-40.75	17.01	-2.72
	(6.56)	(7.60)	(5.55)	(4.30)	(28.96)	(18.07)	(10.09)

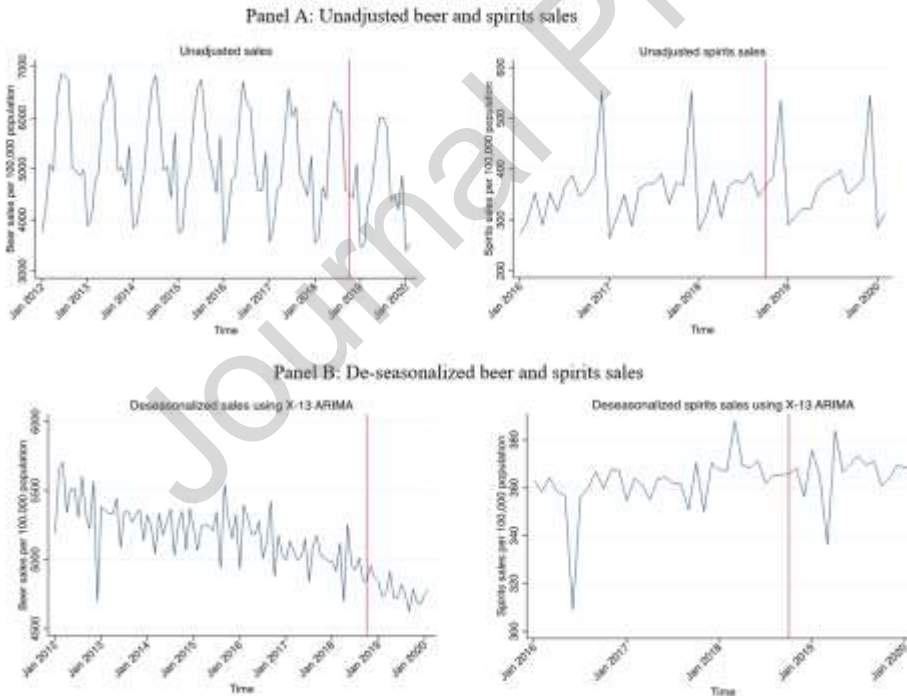
Note: Data are monthly beer sales from Beer Canada for the period January 2012 to February 2020 and monthly spirits sales from Spirits Canada for the period January 2016 to February 2020. Beer and spirit sales (in hectoliters per 100,000 population) are seasonally adjusted using X-13 ARIMA seasonal adjustment (US Census Bureau, 2023). CPI stands for the consumer price index of alcoholic beverages. All models include a linear time trend, indicator for post-legalization period (October 2018 onwards), interactions between post-legalization period and time trend, and controls for consumer price index for alcoholic beverages and unemployment rate (unless stated otherwise). All models are estimated using linear regressions. Newey West standard errors are estimated with maximum lags determined by Cumby-Huizinga test. Average monthly effect is calculated as 'Level change + (Trend change * 9)' where 9 is the average number of post-legalization months during our study period. Significance level: * $p < 0.05$, ** $p < 0.01$

Table 3: Effects of legalization on total beer sales, by beer type

	Bottle	Can	Keg
Legalization	-8.79 (16.87)	-86.75** (26.74)	-12.61 (7.34)
Time trend x Legalization	3.15* (1.35)	-5.16* (2.16)	-1.88** (0.53)
Time trend	-21.69** (3.22)	11.68** (2.31)	0.81 (0.44)
<i>N</i>	98	98	98
Average monthly effect of legalization	19.57 (11.52)	-133.18** (17.47)	-29.49** (4.29)

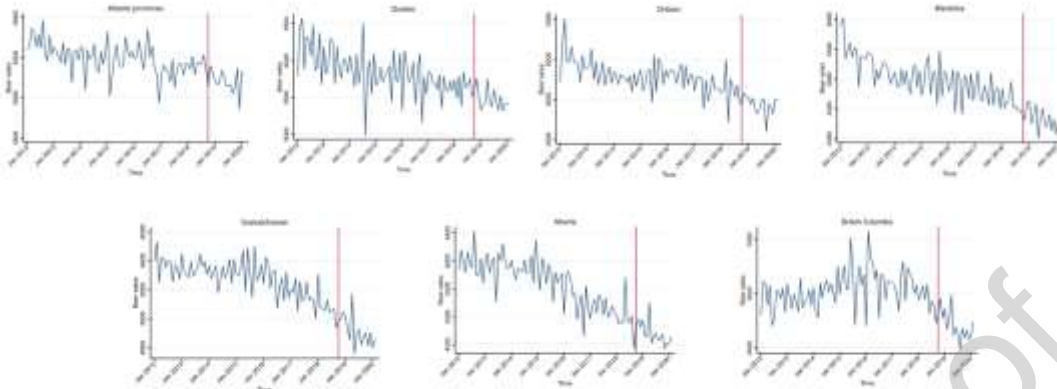
Note: Data are monthly beer sales from Beer Canada for the period January 2012 to February 2020. Beer sales (in hectoliters per 100,000 population) are seasonally adjusted using X-13 ARIMA seasonal adjustment (US Census Bureau, 2023). CPI is the consumer price index of alcoholic beverages. All models include a linear time trend, indicator for post-legalization period (October 2018 to September 2022) and interactions between post-legalization period and time trend. All models are estimated using linear regressions. Newey West standard errors are estimated with maximum lags determined by a Cumby-Huizinga test. Average monthly effect is calculated as ‘Level change + (Trend change * 9)’ where 9 is the average number of post-legalization months during our study period. Significance level: * $p < 0.05$, ** $p < 0.01$

Figure 1: Beer and spirit sales in Canada, unadjusted and de-seasonalized



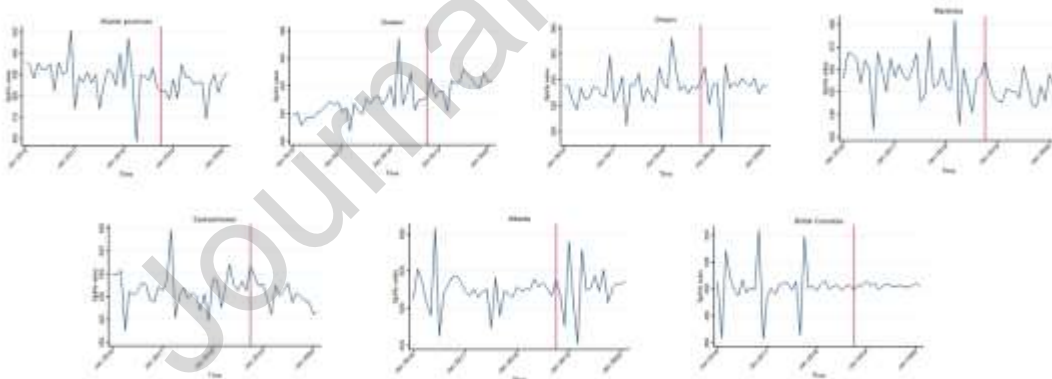
Note: Beer and spirits sales (in hectoliters) for the period January 2012 to February 2020; unadjusted monthly sales and monthly sales de-seasonalized using X-13 ARIMA. Solid red line indicates month and year of non-medical cannabis legalization (October 2018).

Figure 2: Beer sales by province, de-seasonalized



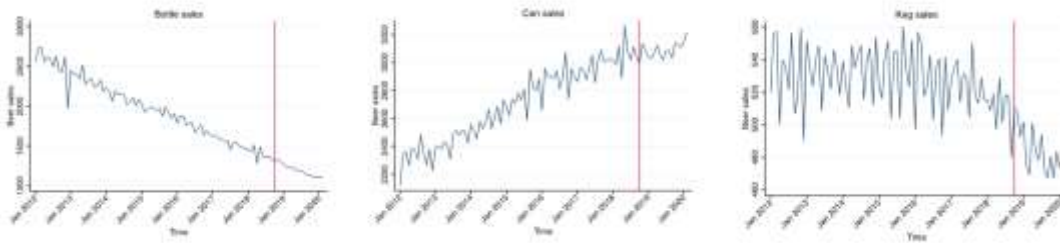
Note: De-seasonalized beer sales for the period January 2012 to February 2020 for each Canadian province. Beer sales are measured in hectoliters per 100,000 population. Solid red line indicates month and year of non-medical cannabis legalization (October 2018).

Figure 3: Spirits sales by province, de-seasonalized



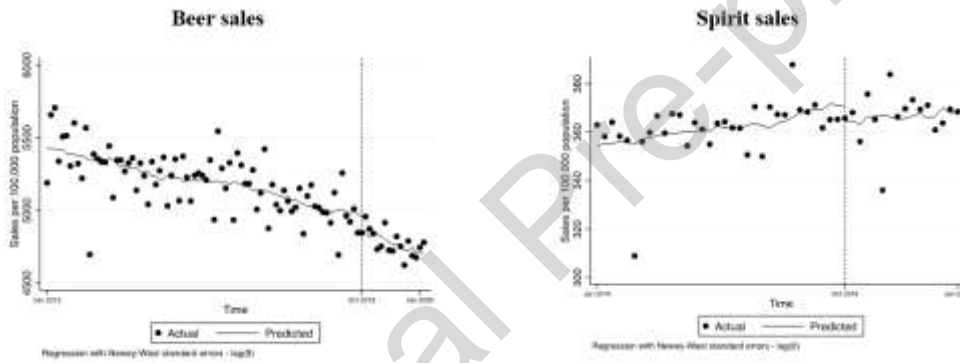
Note: De-seasonalized spirits sales for the period January 2016 to February 2020 for each Canadian province. Spirit sales are measured in hectoliters per 100,000 population. Solid red line indicates month and year of non-medical cannabis legalization (October 2018).

Figure 4: Beer sales by beer type, de-seasonalized



Note: De-seasonalized beer sales for the period January 2012 to February 2020 for each type of beer. Beer sales are measured in hectoliters per 100,000 population. Solid red line indicates month and year of non-medical cannabis legalization (October 2018).

Figure 5: Segmented regression, Canada-wide beer and spirit sales



Note: De-seasonalized beer and spirits sales before and after non-medical cannabis legalization – observed (dots) and modelled (line). Beer and spirits sales are measured in hectoliters per 100,000 population. Dashed line indicates month and year of non-medical cannabis legalization (October 2018).

Author contributions

HVN conceptualized and designed the study, analyzed and interpreted the results and contributed to manuscript writing and revisions. SM conducted the data analysis, interpreted the results, and contributed to manuscript writing and revisions. LB, SB and PG contributed to interpretation of results and manuscript writing and revisions. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Author Disclosures

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Nothing declared

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Conflict of interest

No conflict declared

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Declaration of interest

No conflict declared

Highlights

- Canada's non-medical cannabis legalization was associated with decline in beer sales.
- All provinces except the Atlantic provinces experienced a decline in beer sales.
- Sales of canned and kegged beer decline but there was no reduction in sales of bottled beer.
- The non-medical cannabis legalization was associated with no change in spirits sales.

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