The Potential Health Impact of an Alcohol Minimum Unit Price in Québec: An Application of the International Model of Alcohol Harms and Policies

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ABSTRACT. Objective: Alcohol minimum unit pricing is a strategy capable of reducing alcohol-related harm from cheap alcoholic beverages. We used the International Model of Alcohol Harms and Policies (InterMAHP), an open-access alcohol harms estimator and policy scenario modeler, to estimate the potential health benefits of introducing minimum unit pricing in Québec, Canada. **Method:** Aggregated mortality and hospitalization data were obtained from official administrative sources. Alcohol sales and pricing data were obtained from the partial government retail monopoly and Nielsen. Exposure data were from the Canadian Substance Use Exposure Database. Average price changes under two minimum-unit-pricing scenarios were estimated by applying a product-level pricing analysis. The online InterMAHP tool was used to automate the estimation of observed alcohol-attributable harm and what was projected in each policy scenario. **Results:** Alcohol was estimated to cause 2,850 deaths and 24,694 hospitalizations in Québec in 2014. Introducing minimum unit pricing of CAD$1.50 was estimated to reduce consumption by 4.4%, alcohol-attributable deaths by 5.9% (95% CI [0.2%, 11.7%]), and alcohol-attributable hospital stays by 8.4% (95% CI [3.2%, 13.7%]). Higher minimum unit pricing of CAD$1.75 was estimated to reduce alcohol-attributable deaths by 11.5% (95% CI [5.9%, 17.2%]) and alcohol-attributable hospital stays by 16.3% (95% CI [11.2%, 21.4%]). **Conclusions:** The results of this policy modeling study suggest that the introduction of minimum unit pricing between CAD$1.50 and $1.75 would substantially reduce the alcohol-caused burden of disease in Québec. The quantification of alcohol-caused death and disability, and the changes in these measures under two scenarios, was significantly automated by the open-access resource, InterMAHP. (*J. Stud. Alcohol Drugs, 81,* 631–640, 2020)

ALCOHOL IS RESPONSIBLE for a high burden of disease globally, causing approximately 3 million deaths and 133 million disability-adjusted life years lost annually (World Health Organization [WHO], 2018). To address this, WHO developed the Global Strategy to Reduce the Harmful Use of Alcohol (WHO, 2010), which provides policy options and interventions across 10 key areas, including alcohol pricing policies, physical availability, and marketing. Among these, pricing options have consistently earned the highest feasibility and impact rankings when measured by alcohol policy experts (Babor et al., 2010; Bruun et al., 1975; Nelson et al., 2013). A recent analysis of alcohol policy "best buys" concluded that pricing strategies had the highest cost-effectiveness among global policy strategies (Chisholm et al., 2018). Comprehensive meta-analyses have reported that a 10% increase in the price of alcohol would lead to a 4.4% decrease in alcohol sales (Wagenaar et al., 2009) and that price increases were likewise associated with a host of health benefits, including decreased alcohol-related disease and injury, violence, and motor vehicle collisions (Wagenaar et al., 2010).

An alcohol minimum-pricing strategy gathering support internationally is a minimum unit price (MUP). This strategy sets a floor price below which a *standard drink*—defined by pure alcohol content (in Canada, 13.5 g ethanol)—cannot be sold. MUP policies are applied to all alcoholic beverages (including beer, wine, distilled spirits, cider, coolers, and premixed drinks) and have the effect of preventing the sale of cheap, high-strength drinks (i.e., the drinks with the highest "bang for the buck"). Studies have suggested that cheap alcohol is a cause of hazardous alcohol use, and heavy drinkers have been estimated to experience the greatest benefit, in terms of decreased consumption, upon the implementation of an MUP (Holmes et al., 2014). MUP policies are easy to understand and to communicate to the public: They associate a beverage category–unified floor price with all alcoholic drinks, although typically there are separate MUP levels for off-premises and on-premises sales.

An MUP of 50 pence per 8 g of pure alcohol unit was introduced in Scotland in May 2018 (Giles et al., 2018). This would correspond in Canada to ~CAD$1.42/standard drink (converted online June 24, 2019). (All dollar amounts are in Canadian dollars.) Although early in the MUP evaluation process, a 6-month post-implementation briefing note from NHS Health Scotland reported a smaller increase in

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the volume of pure alcohol sold in Scotland (4%) than in England and Wales (7%)—that is, a relative decrease in the intervention group compared with the control group (Giles et al., 2018). If subsequent and final MUP evaluation provides similar results, it may add further impetus to international calls for MUP policy strategies.

In Canada, alcohol causes pronounced harm: 14,800 deaths and $14.6 billion in health care, lost production, and criminal justice costs in 2014 (Canadian Substance Use Costs and Harms Scientific Working Group, 2018). In response, several Canadian provinces have implemented minimum pricing strategies, which have been shown to lead to decreases in alcohol consumption (Stockwell et al., 2012a, 2012b), alcohol-attributable deaths (Zhao et al., 2013), alcohol-attributable hospital visits (Sherk et al., 2018; Stockwell et al., 2013), and certain types of alcohol-related crime (Stockwell et al., 2015, 2017b).

The Canadian province of Québec has not implemented an MUP strategy, although there exists a minimum price per liter of beer beverage (not per standard drink). In 2009, the recommended MUP for Canadian off-premise alcohol sales was $1.50 (Thomas et al., 2017), which would be just below $1.75 in 2018 (Quebec Inflation Calculator, 2019). Policy-makers considering the introduction of one of these MUP levels demand projections of the changes in sales, consumption, and alcohol-attributable harms that would occur if they were to act. The aims of this study were therefore twofold: (a) to estimate the effect on alcohol prices, sales, and consumption of two MUP scenarios in Québec, representing a $1.50 (Scenario 1) and $1.75 (Scenario 2) MUP per Canadian standard drink, and (b) based on the above consumption changes, to specify and employ methods that automate the estimation of the changes in alcohol-attributable mortality and hospitalizations that would be experienced by Québécois under each scenario compared with the base case.

The recent, open-access provision of an alcohol harms and policy modeler, the International Model of Alcohol Harms and Policies (InterMAHP), makes possible the second study aim using standardized program software available from www.intermahp.cisur.ca. The alcohol harms estimation functionality of InterMAHP is described elsewhere (Sherk et al., 2017, 2020). However, the added capability of estimating changes in alcohol-attributable harms is given summary treatment, and these methods are then used toward the second study aim.

Method

Data sources

Per capita consumption and prevalence and patterns of alcohol use in Québec for 2014 were taken from the Canadian Substance Use Exposure Database (CanSUED), a customized database maintained by the Canadian Institute for Substance Use Research (Canadian Substance Use Costs and Harms Scientific Working Group, 2018). Record-level inpatient hospitalization data were sourced from the Québec hospital patient information system (MED-ÉCHO) of the Ministère de la Santé et des Services sociaux (MSSS). Mortality data were obtained from Québec's Registre des événements démographiques (vital statistics database).

Product-level alcohol sales data for wine, distilled spirits, and liqueurs were obtained from the partial government retail monopoly, Société des alcools du Québec. As beer products were largely sold in convenience stores and grocery stores, beer sales data were purchased from Nielsen, a market research company that collects and makes available these data, which covered about 24% of beer sales by volume. Because this underestimated actual beer volume sold, beer figures were adjusted upward to match aggregate 2014 provincial data available from Statistics Canada (Statistics Canada, 2019).

General approach to the estimation of alcohol-attributable mortality and morbidity

The following generalized approach for estimating alcohol-attributable mortality and morbidity was used. A more comprehensive description is found in Sherk et al. (2017):

1. Enumerating alcohol-related morbidity and mortality. Alcohol-related conditions were identified and operationalized as recommended by InterMAHP (Sherk et al., 2017). Each record in the death and hospitalization data was tallied as up to one alcohol-related condition (i.e., a mortality record may be counted toward zero or one alcohol-related health condition, depending on the diagnosis codes present), using the primary-cause algorithm. The primary-cause algorithm for mortality records assigns a weight of 1.0 to the primary cause of death, whereas, for hospitalization records, the primary diagnosis was assigned a weight of 1.0 unless the record was an injury or poisoning (ICD10 begins with S or T). In the case of injury or poisoning, the record was searched for the first external cause code (ICD10 begins with V,W,X,Y), which was given a weight of 1.0. All other diagnoses were given a weight of zero; this primary-cause algorithm is standard practice in alcohol epidemiology (Sherk, et al., 2017). These counts were then collected into population subgroups defined by gender and age group. The age groups for this study were defined as 0–14, 15–34, 35–64, and ≥65, as these were the default groups recommended by InterMAHP and match those used in the 2018 WHO Global Status Report on Alcohol and Health (WHO, 2018).

2. Estimation of alcohol-attributable fractions. Conditions that are wholly attributable to alcohol were assigned an alcohol-attributable fraction (AAF) of 1.0, by definition. For partially attributable conditions, the estimation of indirect AAFs was automated by InterMAHP. The program software uses the modern AAF formula as presented in Sherk et al.

(2017) and modified from Kehoe et al. (2012). The modern AAF requires the following pieces of information:

(A) *A continuous prevalence distribution of average daily alcohol consumption for each population subgroup:* For each population subgroup, the continuous prevalence distribution was calculated using a single-parameter definition of the gamma distribution (Kehoe et al., 2012; Rehm et al., 2010; Sherk et al., 2017). This formulation of the gamma distribution is uniquely defined in each population subgroup by mean consumption.

(B) *Relative risk functions and estimates for each alcohol-related condition:* Relative risk functions for current drinkers and relative risk point estimates for former drinkers were collected from the international meta-analytic literature for InterMAHP (Sherk et al., 2017) and are similar to those used in the 2018 Global Status Report on Alcohol and Health (Rehm et al., 2017b; WHO, 2018).

3. Estimation of alcohol-attributable mortality and morbidity. Steps 1 and 2 created counts and AAFs for each condition, gender, and age group for Québec in 2014. As the final step, alcohol-attributable estimates were produced by multiplying the enumerated count by the AAF, for each alcohol-related condition, gender, age group, and outcome (mortality or hospitalization).

Estimation of the impact of each MUP scenario on alcohol prices, sales, and consumption

Changes in per capita consumption under each MUP scenario were estimated using the following strategy. First, product-level Société des alcools du Québec and Nielsen data were used to estimate the volume-weighted effective price paid per standard drink ($/standard drink) across beverage and outlet types. Next, under the two MUP scenarios of $1.50/standard drink and $1.75/standard drink, we calculated the percentages of products and ethanol by volume that were currently cheaper than the MUP. The scenarios were then "implemented"—this had the hypothetical effect of raising all product-level prices to at least the floor MUP—and adjusted volume-weighted effective $/standard drink were calculated. This resulted in overall average percentage changes in minimum alcohol prices under each scenario.

These changes in minimum alcohol prices were used to estimate the potential change in total alcohol sales, used as a proxy for consumption, by applying a contextualized price elasticity of alcohol demand when the minimum price is raised: -0.34 from a previous study in the Canadian province of British Columbia (Stockwell et al., 2012a). Québec and British Columbia have been shown to have relatively similar levels and patterns of consumption (Paradis et al., 2010).

Next, as the gamma distribution-defined continuous prevalence distribution of daily alcohol consumption depends only on mean population subgroup consumption, we were able to model the changes in each gamma distribution by applying these percentage consumption changes. Again, this process was fully automated by InterMAHP (Sherk et al., 2017, 2020).

Estimation of the impact of each MUP scenario on alcohol-attributable mortality and morbidity

1. Estimation of changes in the prevalences of binge, current, and former drinkers. The AAFs for injuries (WHO, 2018) and ischemic heart disease and ischemic stroke (Rehm et al., 2017a) are modified by binge drinking prevalence. It was therefore necessary to estimate changes to the prevalence of binge drinkers under each MUP scenario. In Canada, *binge drinking* is defined as five or more standard drinks per occasion for men and four or more standard drinks per occasion for women (Canadian Substance Use Costs and Harms Scientific Working Group, 2018).

Estimation of this prevalence change for each scenario was automated by InterMAHP (Sherk et al., 2017) by calculating the prevalence of "chronic bingers" using the gamma distribution for the base case and for each scenario in turn. Chronic bingers were drinkers who, on average, consumed five or more standard drinks daily for men or four or more standard drinks daily for women; chronic binge drinking was calculated by the following:

$$P_{CB} = \int_c^z P(x)dx, \tag{1}$$

where P_{CB} is the prevalence of chronic bingers, z is an estimate of the upper limit of daily consumption, c is the definition of bingeing in grams of ethanol per occasion, and $P(x)$ is the continuous prevalence distribution of average daily alcohol consumption (Sherk et al., 2017). Next, the resulting binge prevalence was calculated with the following formula:

$$P_{BD,Sx} = P_{BD,Base} * \frac{P_{CB,Sx}}{P_{CB,Base}}, \tag{2}$$

where $P_{BD,Sx}$ is the prevalence of binge drinking in scenario x and $P_{BD,Base}$ is the prevalence of binge drinking in the base case.

In each scenario, it was assumed that the changes in consumption did not change the prevalence of former drinkers or current drinkers. This potential policy change would not affect former drinker status, and estimating zero change in the prevalence of current drinkers followed previous alcohol policy analyses (Stockwell et al., 2017a, 2018).

2. Estimation of changes for partially attributable conditions. AAFs for partially attributable conditions were calculated by InterMAHP using the modern AAF formula and gamma distribution. An adjusted gamma distribution in each scenario was uniquely estimable based on the calculated percentage consumption change (since the employed gamma distribution is dependent only on average daily consumption). This change follows through the AAF calculation to provide an adjusted AAF in each scenario for each alcohol-related condition, gender, and age group.

Next, an adjustment was applied that allowed for modification of the total number of deaths or hospitalizations in each condition, gender, and age group (i.e., the count to which the AAF was subsequently applied):

$$M_{Sx} = M_{Base} + (M_{Sx}AAF_{Sx} - M_{Base}AAF_{Base}), \qquad (3)$$

where total mortality in scenario x (M_{Sx}) equals mortality in the base case (M_{Base}) plus an adjustment representing the difference in alcohol-attributable mortality in scenario x ($M_{Sx}AAF_{Sx}$) and the base case ($M_{Base}AAF_{Base}$). This adjustment would be positive for a consumption increase and negative for a decrease. Rearranging Formula 3 allows us to solve for the adjustment factor, which is now a component of the final calculation:

$$AAM_{Sx} = M_{Sx} \times AAF_{Sx} = M_{Base} \times \frac{1 - AAF_{Base}}{1 - AAF_{Sx}} \times AAF_{Sx}, \quad (4)$$

where AAM_{Sx} is the number of alcohol-attributable deaths under scenario x, the fraction is the adjustment factor, and AAF_{Base} and AAF_{Sx} are the InterMAHP-calculated AAFs under the base case and scenario x (Sherk et al., 2017; Stockwell et al., 2017a, 2018).

3. Estimation of changes for wholly attributable conditions. As wholly attributable conditions have AAFs of 1.0, by definition, it was necessary to create methodology toward estimating the change in these conditions under differing consumption scenarios. This method has been specified in detail (Churchill et al., 2020), is used in the Sheffield Alcohol Policy Model (Brennan et al., 2015), and has been used in previous policy modeling projects (Stockwell et al., 2017a, 2018). In brief, an absolute risk function (ARF) was estimated for each condition, gender, and age group. The ARF was then functionally analogous to the relative risk functions for current drinkers used in the modern AAF formula for partially attributable conditions. Integrating the adjusted gamma distribution, in each scenario, against the ARF provides an estimated change in the number of wholly attributable conditions; this process was automated by InterMAHP (Sherk et al., 2017, 2020).

4. InterMAHP: Estimation of changes to alcohol-attributable mortality and morbidity. InterMAHP automates the necessary calculations in the three preceding subsections and estimates the impact on alcohol-attributable mortality and morbidity given the assessed changes in alcohol prices, sales, and consumption. These computations are completed at the most granular level—health condition by gender by age grouping.

Estimating confidence intervals

Confidence intervals (CIs) for AAFs were estimated following the methods presented in Gmel et al. (2011). In brief, a Monte Carlo approach was used, which consisted of randomly drawing all model parameters 10,000 times and following model calculations through for each condition, gender, and age group. The resulting model estimates were treated as a distribution, and 95% CIs were created by selecting values representing the 2.5th and 97.5th percentiles.

Statistical analyses

InterMAHP is programmed in R version 3.5 (R Core Team, 2018). The statistical package SAS Version 9.4 (SAS Institute Inc., Cary, NC) was used to apply AAFs to death and hospitalization counts and for results aggregation.

Results

Alcohol prices, sales, and consumption, observed and estimated impact of minimum unit pricing policies

The observed number of products and ethanol volume representing alcohol sales in Québec in 2014 are shown in Table 1, by beverage category. There were 18,914 products sold, which contained about 60 million liters of ethanol. The remaining columns present the quantity and percentage of products and ethanol volume that would be affected in each MUP scenario. A MUP of \$1.50 would affect only 2.5% of products; however, these products account for 24.1% of ethanol sales. A \$1.75 MUP would affect 5.4% of products, but more than half (56.3%) of sales by ethanol volume. Among beverage categories, distilled spirits would be the most affected by this implementation, as 68.5% and 82.6% of ethanol volume, respectively, would be subject to a price increase under the MUP scenarios. Wine would be the least affected by MUP strategies, as only 1.0% of products and 11.9% of ethanol would be affected by the \$1.50 MUP, and 2.6% of products and 32.8% of ethanol would be affected by the \$1.75 MUP.

Table 2 summarizes the impact of each MUP scenario on affected alcohol products in each beverage category and overall. The implementation of a \$1.50 MUP would result in a 12.8% increase among affected products, whereas the higher \$1.75 MUP would result in a 25.3% increase.

The application of the price elasticity in the Canadian context (-0.34, see the Method section) results in estimated reductions in per capita consumption of 4.35% in the first scenario and 8.59% in the second scenario.

Alcohol-attributable mortality, observed and estimated impact of MUP policies

Alcohol-attributable deaths in Québec in 2014, by health condition category, are shown in Table 3 for the observed case, Scenario 1 (\$1.50 MUP), and Scenario 2 (\$1.75 MUP). Alcohol was found to be causally responsible for

Table 1. Observed alcohol sales and volume and percentage of ethanol affected by MUP scenarios, by beverage category and total, Québec 2014

	Observed		No. and percentage of products and vol. affected by Scenario 1—$1.50 MUP				No. and percentage of products and vol. affected by Scenario 2—$1.75 MUP			
	Products	Ethanol vol.	Products		Ethanol vol.		Products		Ethanol vol.	
Beverage category	No.	Vol. (1,000 L)	No.	% of total	Vol. (1,000 L)	% of total sales	No.	% of total	Vol. (1,000 L)	% of total sales
Beer, cider, coolers	1,343	31,700	81	6.0%	6,690	21.1%	198	14.7%	20,693	65.3%
Wine	15,176	19,173	149	1.0%	2,290	11.9%	388	2.6%	6,295	32.8%
Fortified wine, liqueurs	826	2,469	22	2.7%	934	37.9%	60	7.3%	1,307	52.9%
Distilled spirits	1,569	6,589	223	14.2%	4,516	68.5%	314	20.0%	5,444	82.6%
Total	18,914	59,932	475	2.5%	14,430	24.1%	960	5.4%	33,740	56.3%

Notes: MUP = minimum unit price/minimum price per standard drink; no. = number; vol. = volume.

2,850 deaths (95% CI [2,685, 3,012]) in Québec. Among condition categories, cancer caused the highest burden of alcohol-attributable mortality at 1,013 deaths, followed by cardiovascular conditions (723 deaths), unintentional injuries (267 deaths), and intentional injuries (266 deaths).

Under two potential MUP policy implementations, the modeling methodologies used found significant reductions in alcohol-attributable mortality under each scenario. Implementing an MUP of $1.50 would have the result of preventing 169 alcohol-attributable deaths (95% CI [-333, -7]) in Québec in 2014; this corresponds to a decrease of 5.9%. Scenario 2, which modeled a higher MUP of $1.75, was estimated to result in 2,523 alcohol-attributable mortalities, a decrease of 327 deaths (11.5%) compared with the observed result. By condition category, neuropsychiatric conditions were most responsive to potential policy change, with estimated 12.0% and 23.2% reductions in alcohol-attributable deaths in Scenarios 1 and 2, respectively.

Alcohol-attributable deaths, by gender and age group, are shown in Table 4. Alcohol caused nearly four times as many deaths among men (2,228 deaths, 95% CI [2,140, 2,313]) than among women (622 deaths, 95% CI [544, 699]). We observed a gradient in the harm-reduction response under these MUP scenarios: in each scenario, younger age groups experienced a greater proportional reduction in mortality than did older age groups. Women also experienced more protection in both Scenario 1 and Scenario 2 relative to men.

Supplemental Table 1 shows alcohol-attributable mortality under each scenario and by 41 alcohol-related health conditions. (Supplemental material appears as an online-only addendum to this article on the journal's website.) Under each MUP scenario, alcohol dependence would have the largest absolute decrease in mortality, as a $1.50 MUP was estimated to prevent 38 deaths and a $1.75 MUP was estimated to prevent 73 deaths from this condition. Other conditions with substantial absolute decreases were other intentional self-harm, such as suicide (18 fewer deaths in Scenario 1 and 35 fewer deaths in Scenario 2), ischemic heart disease (16 and 30), and colorectal cancer (10 and 20).

Alcohol-attributable hospitalizations, observed and estimated impact of MUP policies

Table 5 presents alcohol-attributable hospitalizations by condition category. Alcohol caused 24,694 (95% CI [23,338, 26,017]) hospitalizations in Québec in 2014. About 49% of these alcohol-attributable hospitalizations were caused by unintentional injuries such as falls and accidental poisonings due to alcohol and other substances. After unintentional injuries, neuropsychiatric conditions (3,911 alcohol-attributable hospitalizations), cancer (3,250), digestive conditions (2,626), and communicable disease (1,594) were responsible for 1,000 or more alcohol-attributable hospital stays. Alcohol consumption caused a decrease in the number of hospital stays for diabetes and cardiovascular conditions. However, each MUP scenario resulted in gains in these categories as well (i.e., more hospital stays prevented).

In general, our results support the idea that alcohol-attributable hospitalizations would be more responsive to MUP policy changes than alcohol-attributable mortalities.

Table 2. Estimated impact of MUP scenarios on average alcohol prices of affected products, by beverage category and total, Québec 2014

	Scenario 1—$1.50 MUP		Scenario 2—$1.75 MUP	
Beverage category	Change ($)	Change (%)	Change ($)	Change (%)
Beer, cider, coolers	$0.154	12.1%	$0.351	26.4%
Wine	$0.165	13.2%	$0.226	16.4%
Fortified wine, liqueurs	$0.129	10.6%	$0.209	14.9%
Distilled spirits	$0.201	16.2%	$0.398	31.1%
Total[a]	$0.162	12.8%	$0.348	25.3%

Notes: MUP = minimum unit price/minimum price per standard drink. [a]Weighted by sales volume from Table 1.

TABLE 3. Alcohol-attributable mortality, observed and under two MUP scenarios, by condition category, Québec 2014

	Quebec in 2014	Scenario 1—$1.50 MUP		Scenario 2—$1.75 MUP	
Condition category	Observed [95% CI]	Estimate [95% CI]	% Change [95% CI]	Estimate [95% CI]	% Change [95% CI]
(1) Communicable diseases	131 [125, 136]	124 [119, 129]	-5.3% [-9.2%, -1.5%]	118 [113, 123]	-9.9% [-13.7%, -6.1%]
(2) Cancer	1,013 [964, 1,062]	979 [930, 1,027]	-3.4% [-8.2%, +1.4%]	946 [897, 994]	-6.6% [-11.5%, -1.9%]
(3) Diabetes	-125 [-145, -106]	-124 [-143, -105]	N.A. –	-122 [-142, -103]	N.A. –
(4) Neuropsychiatric conditions	375 [375, 376]	330 [328, 332]	-12.0% [-12.5%, -11.5%]	288 [285, 292]	-23.2% [-24%, -22.1%]
(5) Cardiovascular conditions	723 [665, 782]	694 [636, 752]	-4.0% [-12%, +4%]	667 [610, 725]	-7.7% [-15.6%, +0.3%]
(6) Digestive conditions	118 [116, 121]	111 [108, 113]	-5.9% [-8.5%, -4.2%]	104 [101, 106]	-11.9% [-14.4%, -10.2%]
(7) Motor vehicle collisions	81 [78, 84]	75 [71, 78]	-7.4% [-12.3%, -3.7%]	68 [65, 71]	-16% [-19.8%, -12.3%]
(8) Unintentional injuries	267 [253, 281]	246 [233, 259]	-7.9% [-12.7%, -3%]	227 [215, 239]	-15% [-19.5%, -10.5%]
(9) Intentional injuries	266 [254, 277]	246 [235, 257]	-7.5% [-11.7%, -3.4%]	227 [216, 237]	-14.7% [-18.8%, -10.9%]
Grand total	2,850 [2,685, 3,012]	2,681 [2,517, 2,843]	-5.9% [-11.7%, -0.2%]	2,523 [2,360, 2,683]	-11.5% [-17.2%, -5.9%]

Notes: MUP = minimum unit price/minimum price per standard drink; CI = confidence interval; N.A. = not applicable: percentage changes are omitted when observed counts are negative. Columns may not sum due to rounding.

For example, under Scenario 2, it was found that alcohol-attributable hospitalizations would decrease by 16.3%, whereas alcohol-attributable deaths would decrease by 11.5%. Neuropsychiatric conditions, unintentional injuries, and intentional injuries were the three condition categories that would be most responsive to policy change. Substantial decreases in alcohol-attributable hospitalizations were estimated in both Scenario 1 (2,063 fewer hospital stays) and Scenario 2 (4,014 fewer hospital stays).

Alcohol-attributable hospitalizations, by gender and age group, are presented in Table 6. As with mortalities, men (19,464; 95% CI [18,776, 20,138]) experienced nearly four times as many hospitalizations as women (5,229; 95% CI [4,562, 5,879]). Again, women were estimated to experience greater proportional benefit than men from these policy changes. Harm-reduction gradients by age group were differential by gender: for women, older age groups would experience a greater proportional reduction in harms (save

TABLE 4. Alcohol-attributable mortality, observed and under two MUP scenarios, by gender and age group, Québec 2014

	Quebec in 2014	Scenario 1—$1.50 MUP		Scenario 2—$1.75 MUP	
Gender and age group	Observed [95% CI]	Estimate [95% CI]	% Change [95% CI]	Estimate [95% CI]	% Change [95% CI]
Women					
Total	622 [544, 699]	574 [498, 650]	-7.7% [-19.9%, +4.5%]	531 [456, 605]	-14.6% [-26.7%, -2.7%]
15–34	37 [35, 38]	33 [32, 34]	-10.8% [-13.5%, -8.1%]	30 [28, 31]	-18.9% [-24.3%, -16.2%]
35–64	176 [165, 187]	161 [150, 171]	-8.5% [-14.8%, -2.8%]	146 [136, 157]	-17% [-22.7%, -10.8%]
≥65	409 [344, 474]	380 [316, 444]	-7.1% [-22.7%, +8.6%]	354 [291, 417]	-13.4% [-28.9%, +2%]
Men					
Total	2,228 [2,140, 2,313]	2,107 [2,020, 2,194]	-5.4% [-9.3%, -1.5%]	1,992 [1,904, 2,079]	-10.6% [-14.5%, -6.7%]
15–34	144 [141, 148]	134 [130, 137]	-6.9% [-9.7%, -4.9%]	123 [120, 127]	-14.6% [-16.7%, -11.8%]
35–64	721 [699, 741]	672 [650, 693]	-6.8% [-9.8%, -3.9%]	625 [603, 647]	-13.3% [-16.4%, -10.3%]
≥65	1,362 [1,300, 1,423]	1,301 [1,239, 1,363]	-4.5% [-9%, +0.1%]	1,243 [1,180, 1,304]	-8.7% [-13.4%, -4.3%]
Grand total	2,850 [2,685, 3,012]	2,681 [2,517, 2,843]	-5.9% [-11.7%, -0.2%]	2,523 [2,360, 2,683]	-11.5% [-17.2%, -5.9%]

Notes: MUP = minimum unit price/minimum price per standard drink; CI = confidence interval. Columns may not sum due to rounding.

Table 5. Alcohol-attributable hospitalizations, observed and under two MUP scenarios, by condition category, Québec 2014

Condition category	Quebec in 2014 Observed [95% CI]	Scenario 1—$1.50 MUP Estimate [95% CI]	Scenario 1—$1.50 MUP % Change [95% CI]	Scenario 2—$1.75 MUP Estimate [95% CI]	Scenario 2—$1.75 MUP % Change [95% CI]
(1) Communicable diseases	1,594	1,517	-4.8%	1,443	-9.5%
	[1,531, 1,658]	[1,457, 1,579]	[-8.6%, -0.9%]	[1,385, 1,502]	[-13.1%, -5.8%]
(2) Cancer	3,250	3,119	-4.0%	2,993	-7.9%
	[3,108, 3,390]	[2,979, 3,258]	[-8.3%, +0.2%]	[2,855, 3,131]	[-12.2%, -3.7%]
(3) Diabetes	-133	-132	N.A.	-131	N.A.
	[-154, -112]	[-153, -112]	–	[-152, -111]	–
(4) Neuropsychiatric conditions	3,911	3,443	-12.0%	3,015	-22.9%
	[3,899, 3,923]	[3,415, 3,472]	[-12.7%, -11.2%]	[2,975, 3,056]	[-23.9%, -21.9%]
(5) Cardiovascular conditions	-340	-542	N.A.	-731	N.A.
	[-658, -28]	[-850, -238]	–	[-1,030, -436]	–
(6) Digestive conditions	2,626	2,510	-4.4%	2,399	-8.6%
	[2,544, 2,705]	[2,427, 2,590]	[-7.6%, -1.4%]	[2,315, 2,480]	[-11.8%, -5.6%]
(7) Motor vehicle collisions	620	577	-6.9%	534	-13.9%
	[593, 647]	[550, 602]	[-11.3%, -2.9%]	[509, 558]	[-17.9%, -10%]
(8) Unintentional injuries	12,190	11,240	-7.8%	10,334	-15.2%
	[11,543, 12,816]	[10,640, 11,824]	[-12.7%, -3%]	[9,780, 10,877]	[-19.8%, -10.8%]
(9) Intentional injuries	976	899	-7.9%	824	-15.6%
	[932, 1,018]	[857, 939]	[-12.2%, -3.8%]	[785, 863]	[-19.6%, -11.6%]
Grand total	24,694	22,631	-8.4%	20,680	-16.3%
	[23,338, 26,017]	[21,322, 23,914]	[-13.7%, -3.2%]	[19,421, 21,919]	[-21.4%, -11.2%]

Notes: MUP = minimum unit price/minimum price per standard drink; CI = confidence interval; N.A. = not applicable: percentage changes are omitted when observed counts are negative. Columns may not sum due to rounding.

for the small sample size in the 0–14 age group). However, for men, it appears that younger age groups would benefit more from these policy changes.

Supplemental Table 2 shows alcohol-attributable hospitalizations, observed and under each MUP scenario, by health condition. There are more than 1,000 alcohol-attributable hospitalizations for alcohol psychoses, alcohol dependence, atrial fibrillation and cardiac arrhythmia, falls, and other unintentional injuries. Of these, alcohol psychoses and dependence were projected to experience the largest relative decreases in each policy scenario. In the base case and in each scenario, alcohol was estimated to prevent more than 1,350 hospitalizations due to ischemic heart disease.

Table 6. Alcohol-attributable hospitalizations, observed and under two MUP scenarios, by gender and age group, Québec 2014

Gender and age group	Quebec in 2014 Observed [95% CI]	Scenario 1—$1.50 MUP Estimate [95% CI]	Scenario 1—$1.50 MUP % Change [95% CI]	Scenario 2—$1.75 MUP Estimate [95% CI]	Scenario 2—$1.75 MUP % Change [95% CI]
Women					
Total	5,229	4,473	-14.5%	3,784	-27.6%
	[4,562, 5,879]	[3,848, 5,086]	[-26.4%, -2.7%]	[3,199, 4,359]	[-38.8%, -16.6%]
00–14	17	15	-11.8%	13	-23.5%
	[17, 17]	[15, 15]	[-11.8%, -11.8%]	[12, 13]	[-29.4%, -23.5%]
15–34	1,222	1,100	-10%	986	-19.3%
	[1,165, 1,277]	[1,045, 1,154]	[-14.5%, -5.6%]	[934, 1,037]	[-23.6%, -15.1%]
35–64	3,080	2,700	-12.3%	2,351	-23.7%
	[2,833, 3,323]	[2,465, 2,932]	[-20%, -4.8%]	[2,130, 2,571]	[-30.8%, -16.5%]
≥65	910	659	-27.6%	434	-52.3%
	[546, 1,261]	[322, 986]	[-64.6%, +8.4%]	[123, 738]	[-86.5%, -18.9%]
Men					
Total	19,464	18,158	-6.7%	16,896	-13.2%
	[18,776, 20,138]	[17,474, 18,829]	[-10.2%, -3.3%]	[16,222, 17,561]	[-16.7%, -9.8%]
00–14	22	20	-9.1%	18	-18.2%
	[22, 22]	[20, 20]	[-9.1%, -9.1%]	[18, 18]	[-18.2%, -18.2%]
15–34	3,458	3,222	-6.8%	2,992	-13.5%
	[3,372, 3,543]	[3,135, 3,308]	[-9.3%, -4.3%]	[2,905, 3,078]	[-16%, -11%]
35–64	9,298	8,650	-7%	8,025	-13.7%
	[9,027, 9,561]	[8,376, 8,915]	[-9.9%, -4.1%]	[7,752, 8,290]	[-16.6%, -10.8%]
≥65	6,686	6,265	-6.3%	5,861	-12.3%
	[6,356, 7,011]	[5,944, 6,585]	[-11.1%, -1.5%]	[5,546, 6,174]	[-17.1%, -7.7%]
Grand total	24,694	22,631	-8.4%	20,680	-16.3%
	[23,338, 26,017]	[21,322, 23,914]	[-13.7%, -3.2%]	[19,421, 21,919]	[-21.4%, -11.2%]

Notes: MUP = minimum unit price/minimum price per standard drink; CI = confidence interval. Columns may not sum due to rounding.

Discussion

The results presented in this modeling study suggest that implementing an alcohol MUP in Québec would lead to significant reductions in both deaths and hospitalizations caused by alcohol. If Québec had previously implemented an MUP of $1.50, the drinking population would have experienced 169 fewer deaths and 2,063 fewer hospital stays in 2014. If the government had instead enacted an MUP of $1.75, Québécois would have experienced 327 fewer deaths and 4,014 fewer hospital stays in 2014. Conceptually, the results assume that the policy had been implemented previous to 2014, far enough in the past for alcohol-attributable chronic conditions—such as breast cancer, colorectal cancer, and liver cirrhosis—to develop.

The results provide evidence that MUP policies differentially benefit younger age groups regarding the prevention of alcohol-caused death. A harm-reduction gradient was observed, for both men and women, wherein those 15–34 years of age experienced the greatest proportional reduction in mortality under each MUP scenario, followed by the 35–64 and ≥65 age groups. As per capita consumption in Québec is highest among 15- to 34-year-olds of both genders, drinkers of this age may experience larger average absolute reductions in consumption when MUP policies are introduced, leading to greater health benefits. Policymakers may consider this result, as policies benefiting younger age groups will save more potential years of life and increase economic production by a greater amount than those benefiting older age groups.

It is important to differentiate MUP strategies from general alcohol taxation increases. MUP policies specifically target only the cheapest alcohol products—those delivering the highest pure alcohol—while leaving unchanged alcohol products at other price levels, unlike tax increases. Furthermore, MUP strategies have been estimated to provide the greatest health benefits, in the form of reduced drinking, to the heaviest drinkers (Holmes et al., 2014).

We have presented a series of alcohol policy modeling results calculated through the use of the InterMAHP, an open-access model for estimating alcohol-attributable harms and changes in harms resulting from alcohol policy changes. Global alcohol researchers, given a standard set of data regarding regional alcohol consumption and prevalence and enumerated mortality/morbidity counts, may use InterMAHP to automate portions of projects designed to quantify alcohol-caused harms or to estimate the potential health impact of a realized or hypothetical alcohol policy implementation.

Limitations

This study has inherent limitations. It is a modeling exercise regarding hypothetical alcohol policy changes and not a study of implemented policies. InterMAHP's modeling strategy estimates alcohol-attributable harms through the use of the extensively used modern AAF formulation. However, as many as seven alternate methods exist (Trias-Llimós et al., 2018). Parish et al. (2017) found that the single-parameter gamma distribution used by InterMAHP may result in higher AAF estimates compared with completion of comprehensive distributional best-fit analyses in each population subgroup. Last, InterMAHP does not separately enumerate alcohol-attributable harms to others; this could have led to an underestimation of total alcohol-attributable harms in the current report.

There are reasons to believe that the estimated effects of the MUP policies may be underestimated by our study. First, when calculating per capita consumption changes resulting from MUP implementation, we used a price elasticity of -0.34 from British Columbia (Stockwell et al., 2012a). Research from another province, Saskatchewan, reported a price elasticity of -0.84, more than twice the magnitude of the estimate used here (Stockwell et al., 2012b). If this larger elasticity, or a weighted average of the two, had been used in this study, consumption change estimates, and therefore the estimated reductions in harm, would be far higher than presented.

Next, our hypothetical MUP implementation increased all alcohol priced below each scenario's MUP up to that threshold. This led to product clustering at the MUP in each scenario. We did not use "knock-on" pricing effects, wherein the prices of some of these products are increased in order to differentiate from these new cheapest products. Using these knock-on effects would further increase the magnitude of consumption change and harm impact estimates.

We also note the differences between the minimum price changes in the British Columbia study (Stockwell et al., 2012a), the source of our elasticity, and the hypothetical MUP scenarios in this study. In the former, MUP changes consisted of relatively small incremental increases, against general inflationary erosion (as prices were not CPI-adjusted), over a 20-year period, as opposed to the one-time implementation studied here. The MUP levels in the British Columbia study were also lower (between $0.70 and $1.20, depending on the year and the beverage category), as opposed to the scenarios presented here. These differences in MUP context regarding the application of the British Columbia elasticity to our study are a limitation. However, as above, we note that research from another province, with a similar, single MUP implementation, estimated an elasticity with larger magnitude. Hence, our decision to use the British Columbia elasticity was conservative and resulted in lower estimates of health benefits than if the Saskatchewan elasticity had been used.

Last, we provide consideration of the appropriateness of the gamma distributions toward modeling the prevalence distribution of daily alcohol consumption after the proposed MUP scenarios were invoked. This provides a possible limitation: On the one hand, MUP policies are likely to reduce the consumption of the heavy drinkers in the right-most tail of the gamma distribution disproportionately: This could lead to a post-implementation distribution that is not appropriately modeled by the gamma. However, this would only consider the instantaneous shock of the implementation. On the other hand, after the initial shock, drinkers and non-drinkers will still behave as a social network, continuing to influence each other as per Skog's Collectivity of Drinking Cultures (Skog, 1985). A single, one-parameter distribution, such as the gamma distribution used here, may well be the result of a new societal equilibrium regarding alcohol use, under the new policy parameters determined by MUP implementation. Further study is needed, and opportunities may be presented, such as Scotland's MUP enactment.

Conclusions

Alcohol causes substantial harm in Québec, Canada. In 2014, drinking was causally responsible for 2,850 deaths and 24,694 hospital stays in the province. Of these deaths, 1,013 (36%) were caused by alcohol-attributable cancers. The government of Québec, as well as national and subnational governments worldwide, may consider implementing alcohol MUP strategies, which have been shown to reduce alcohol consumption and related harms (Holmes et al, 2014; Stockwell et al., 2012b, 2017b). This modeling study suggests that implementing an alcohol MUP in the range of $1.50 to $1.75 in Québec would result in a significant and lasting reduction in the harms caused by alcohol in society.

We recommend the International Model of Alcohol Harms and Policies as an open-access set of methodologies and software, which may assist global alcohol researchers toward estimation of the health impacts of realized or hypothetical alcohol policy changes in their region. Estimates of these health impacts are crucial for policymakers engaged in evidence-based policy writing. InterMAHP makes possible timely and comparable estimates of changes in alcohol-attributable harms based on per capita consumption changes brought about by alcohol policy change.

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