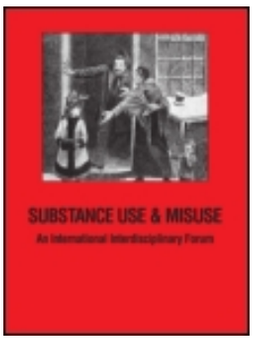

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SOCIETAL INTERVENTIONS

CAN ALCOHOL PRICE POLICIES BE USED TO REDUCE DRUNK DRIVING? EVIDENCE FROM CANADA*

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ABSTRACT

Drunk driving is one of the more serious negative consequences of alcohol consumption. Since consumption of alcohol is sensitive to the price of alcohol, and the occurrence of drunk driving is sensitive to the level of alcohol consumption, the possibility exists for alcohol pricing policies to be used to reduce drunk driving in the population. This paper reviews the evidence on this possibility in the literature and adds results based on data from the Canadian province of Ontario. Multiple regression analysis of time series data for Ontario

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from 1972 to 1990 indicate that, controlling for income, the proportion of young males in the population, changes in the minimum drinking age, and other confounding variables, increasing the price of alcohol has a significant effect in reducing alcohol-related motor vehicle accidents (elasticity = −1.2, $p < .05$) and alcohol-related traffic offenses (elasticity = −0.50, $p < .05$). Overall, the evidence strongly supports the view that alcohol tax and pricing policies can be used to reduce the extent of drunk driving. [Translations are provided in the International Abstracts Section of this issue.]

Key Words: Alcohol; Drunk driving; Traffic offenses price; Elasticity

INTRODUCTION

The focus of this paper will be on economic factors that can be used to reduce drunk driving, one of the harmful consequences of "substance abuse." Drunk driving can result in injury or death of drivers or pedestrians who have been drinking, or of pedestrians, drivers or passengers who have not been drinking if a drunk driver runs into them or their car. Drunk driving can result in property damage to the car of the drunk driver and to any other vehicle and private or public property the drunk driver runs into, such as shop windows, fences, mail boxes, lampposts, trees etc. The damage can be not only physical but also psychological, social or economic, with grief-stricken family members and dependents left behind who have lost their emotional or financial source of support.

In Canada in 1990, there were 139,871 alcohol-involved traffic offenses, for which 112,925 persons were charged, resulting in a rate of 1.24 offenses per person charged. In 1989–90, in Canada, there were 16,566 drunk driving admissions to provincial correctional facilities (jails which hold people for 2 years or less). Drunk driving accounted for 14% of all admissions to provincial jails. Finally, 46% of fatally injured drivers had positive blood alcohol content (1).

Information on alcohol-involved traffic accidents is available from Ontario (Canada's most populous province, where 40% of Canadians live). In 1990, there were 15,791 drivers involved in traffic accidents with ability impaired by drink or who had been drinking. Relative to all traffic accidents in Ontario, alcohol-involved traffic accidents represented 18.9% of all fatal accidents, 5.6% of all non-fatal accidents, and 3.2% of all property damage accidents. Out of all traffic accidents in Ontario, 9.8% involved

pedestrians with ability impaired by drink or who had been drinking; this figure rises to 24% for fatal traffic accidents (2).

The cost of alcohol-related traffic accidents resulting from insurance payments alone was estimated to be CAN$224 million in 1981 (3). The figure is undoubtedly larger today.

DRUNK DRIVING MODEL

For drunk driving to occur, both drinking and driving must occur (Figure 1). Drunk driving can be reduced as a result of interventions that affect one or both of these factors.

At the macro-level alone, the following technological, legal, political, or social interventions have been used to affect the *driving* aspect of the drunk driving equation: better built crash-resistant cars; availability of seat-belts and mandatory seat-belt legislation; lowered speed limits; roadside drunk driver checks such as the RIDE program in Ontario; driver education curricula in schools; and graduated licensing.

A number of interventions have been or can be used to affect the *drinking* part of the drunk driving model. These interventions, many of which consist of regulations under the provincial Liquor Acts, include: raising the legal drinking age; reducing the hours of availability of alcohol

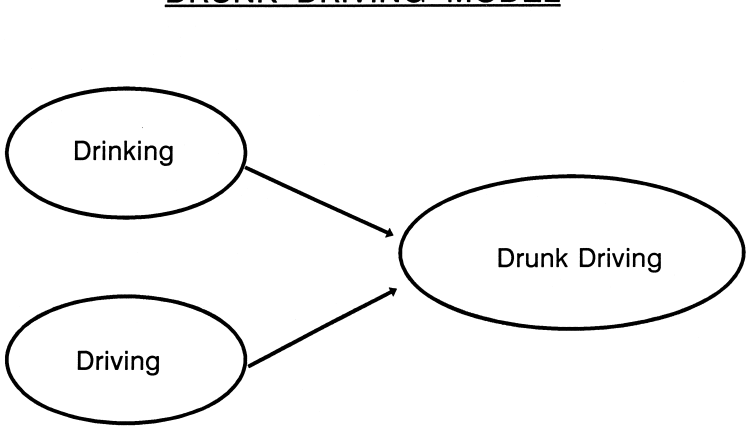

Figure 1. Drunk driving model.

by defining the time when bars and taverns must close (1:00 am in Ontario vs. 3:00 am in the neighboring province of Quebec for instance); limiting the locational availability of on-premise dispensers or of liquor stores providing alcohol for off-premise consumption (e.g., allowing 1500 liquor, beer, and wine store outlets to service a population of 10,000,000 in Ontario vs. some 13,000 outlets to service a population of 7,000,000 in Quebec, or requiring premises that sell alcohol to have a special government license, setting a defined minimum distance between the location of schools and taverns, etc.). Interventions also include providing responsible drinking education programs such as the Server Intervention Programs (SIP) for bartenders, conducting responsible drinking driving public health campaigns through the media, and controlling the price of alcohol.

In this paper we will consider the relationship between the drinking and the drunk driving parts of the model, and how changes that affect drinking can affect drunk driving. In particular, we will consider the effect of changes in price of alcohol on drunk driving.

Model of Drunk Driving Incorporating the Effect of Price of Alcohol

A drunk driving model that incorporates the price effect on drunk driving is shown in Figure 2. In this model, the price of alcoholic beverages affects the amount of alcoholic beverages consumed and, consequently, consumption of alcoholic beverages affects drunk driving. If this model holds true and an increase in the price of liquor reduces alcohol consumption, it is reasonable to suppose that an increase in the price of alcohol will reduce drunk driving problems. In this paper we will examine the evidence for such a model.

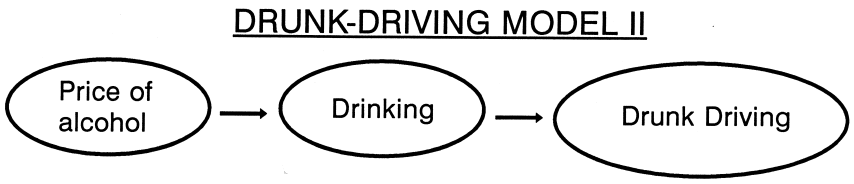

Figure 2. Drunk driving model II: the effect of price.

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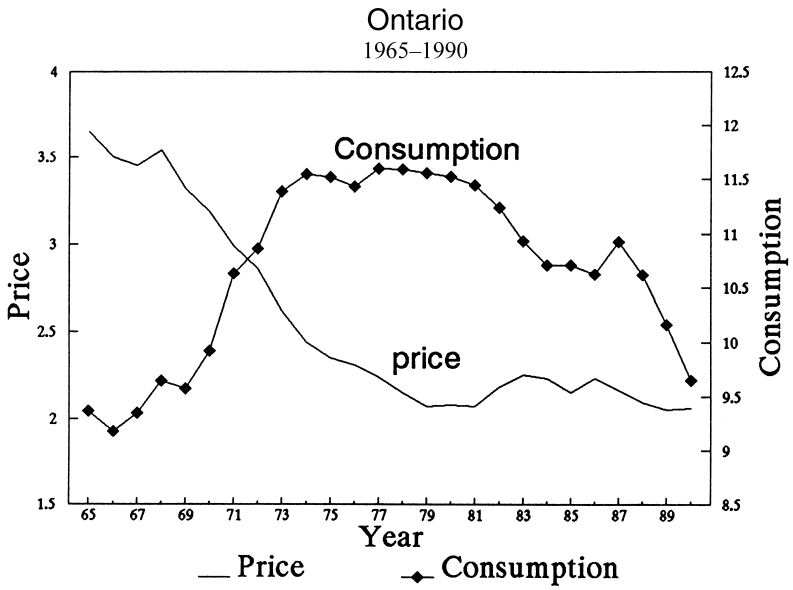
Relationship Between Alcohol Price and Alcohol Consumption

The relationship between the price of alcohol and the consumption of alcoholic beverages is based on that fundamental economic principle which states that as price goes up, consumption goes down, and as price goes down, consumption increases. Some theorists have argued that the consumption of addictive substances might be an exception to this principle, but data from numerous studies would seem to indicate that consumption of alcohol does indeed correspond to the usual economic model of consumption. Let us consider trends in the price of alcohol and the per capita consumption of alcohol for the 25-year period between 1965 and 1989 in Canada and in Ontario (Figure 3). The price of alcoholic beverages (expressed as the Canadian dollar price for 10 litres of absolute alcohol deflated by the personal disposable income per person aged 15 and over, so as to control for the effect of changes in price due solely to the effect of inflation and to growth in population) has been going down since 1968 until about mid-late 1970s, when it remained steady, and then started going up a



Price:cost of 10 litres of absolute alcohol as a percentage of disposable income per person aged 15 and over
Consumption:litres of absolute alcohol per person aged 15 and over

Figure 3. Relationship between the price of alcohol and the consumption of alcohol, Ontario, 1965–1990.

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bit. Meanwhile, consumption of alcohol (taken as litres of absolute alcohol per person aged 15 and over) increased from 1965 to the early mid-1970s, remaining steady thereafter, and falling in the last few years as price went up. In technical terms, there is a negative correlation between price and consumption ($r = -0.81$, $p < .01$ for Ontario, and $r = -0.82$, $p < 0.01$ for Canada) (4,5).

While this is a high negative correlation, it must be noted that a number of other economic factors besides price determine consumption patterns, such as people's income. A host of other social and political factors also play a role in alcohol consumption. For example, drinking age was raised from 18 to 19 years of age in Ontario in 1979, thus reducing the number of consumers, health promotion campaigns were launched throughout Canada to reduce drunk driving, etc. However, the relationship between price and consumption is strong enough for price by itself to account for up to 64% of consumption (6).

Price Elasticities of Alcoholic Beverages

A number of studies have attempted to model the relationship between alcohol consumption and economic factors, such as price and income, using elasticities. We refer to unit elasticity (elasticity = 1), if price goes up by, say, 10% and consumption goes down by the same percentage, which would be 10% in this case. A good is said to be price inelastic (elasticity < 1, in absolute value), if a 10% price increases provokes a less than 10% drop in consumption. It is said to be price elastic (elasticity > 1), if a 10% price increase leads to a more than 10% drop in consumption. The effect on consumption of changing the price of an alcoholic beverage that is price inelastic will be smaller, while it will be larger in the case of a beverage that is price elastic.

Table 1 summarizes the results of a number of studies of alcohol consumption and price elasticities. In general, studies in both the U.S. and Canada have shown that the price elasticities of alcohol depend on a number of factors, including the type of alcoholic beverage, whether short- or long-term effects are considered, and the segment of the consuming population being considered.

In the U.S., an early study (7) found that the consumption of liquor was price inelastic, although a later study (12) reported liquor consumption to be price elastic.

A 1974 study by Johnson and Oksanen of Canadian data found that the consumption of alcoholic beverages was price elastic in the long run for spirits and wine, with other alcoholic beverages price inelastic. A subsequent

Table 1. Alcohol Consumption and Price Elasticities of Alcohol

Beer	Wine	Spirits	Total/ Absolute Alcohol	Comments	Sources and Jurisdiction
		−0.79			Simon (1966) U.S.A. (7)
−0.22	−0.5	−0.91		Short-term	Johnson and Oksanen (1974)
−0.379	−1.599	−1.301		Long-term	Canada (8)
−0.22	−1.13	−0.68		Short-term	Johnson and Oksanen (1977)
−0.29	−1.70	−1.36		Short-term	Canada (9)
−0.37	−0.61	−0.05		Domestic alcohol	Adrian and Ferguson (1987)
−0.84	−1.27	−0.96		Imported alcohol	Canada (10)
−0.17	−0.53	−0.24		Combined domestic and imported alcohol	
−0.3 to −0.4	−0.5 to −1.0	−1.0 to −1.5			Ornstein (1980) U.S.A. (11)
		−1.6			Cook (1981) U.S.A. (12)
−2.3				For youth	Phelps (1988) U.S.A. (13)
−0.48	−0.51	−0.54		Domestic alcohol dynamic model	Brox, Andrikopoulos, and
−1.02	−0.70	−0.34		Imported alcohol dynamic model	Carvalho (1992) Canada (14)
			−1.14	Males, "heavy drinking"	Kenkel (1993) U.S.A. (15)
			−0.71	Females, "heavy drinking"	
			−0.95	Young males, "heavy drinking"	
			−3.54	Young females "heavy drinking"	

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study of theirs (9) again found that the consumption of alcoholic beverages was price elastic for spirits and wine in the long run, but they also found that wine consumption was price elastic in the short run, with other alcoholic beverages being price inelastic.

In our own analysis (10) we found that the consumption of imported wine was price elastic, whereas other alcoholic beverages were price inelastic. These findings were generally confirmed by Brox et al. (14).

Phelps (13) found that, in the United States beer consumption was price elastic for youth, since beer tended to be the alcoholic beverage of choice for this age group, which generally had lower disposable income than other consumer groups. This finding has important implications for controlling drunk driving, since youth account for a disproportionately high rate of alcohol related motor vehicle accidents.

Kenkel (15) found that, in the United States, "heavy drinking" in males was price elastic, but not in females. However, in young persons aged between 18 and 21 years of age, "heavy drinking" was price inelastic in males and price elastic in females.

The Relationship Between Income and Alcohol Consumption

As in the case of price elasticities, the impact on consumption of changes in income will be smaller for beverages that are income inelastic, and larger for those that are income elastic.

The results of a number of studies of alcohol consumption and income elasticities are summarized in Table 2. Again, there were variations depending on the type of alcoholic beverages. Many studies found that income elasticity for the consumption of most alcoholic beverages did not differ significantly from zero. However, in the United States (16,20), in Australia (20), and in Canada (10,19,20), wine consumption was found to be income elastic. In addition, in Canada, Adrian and Ferguson (10) found that the consumption of imported beer was income elastic, with consumption increasing as income increased. A more recent study (14) found that, in Canada, imported beer and imported and domestic wine had high income elasticities.

The Relationship Between Alcohol Consumption and Drunk Driving

Mann and Anglin (23) reviewed the literature on the relationship between alcohol availability, alcohol consumption, and various measures of traffic safety. All 11 studies of consumption and traffic safety found a

Table 2. Alcohol Consumption and Income Elasticities

Beer	Wine	Spirits	Total/ Absolute Alcohol	Comments	Sources and Jurisdiction
	1.5	0.6			Niksanen (1962) U.S.A. (16)
			0.88	Short-run	Schweitzer (1965) Canada (17)
			0.94	Long-run	
0.94				Excluding effect of foreign-born	Hogarty and Elzinga (1972)
0.43				Including effect of foreign-born	U.S.A. (18)
0.035	−0.008	0.227	0.09	Short-run	Johnson and Oksanen (1974)
0.060	−0.022	0.399	0.19	Long-run	Canada (8)
			1.009		Lau (1975) Finland (19)
0.205	1.427	0.679	0.52		Lau (1975) Canada (19)
	−0.148				Labys (1976) France (20)
	2.3			Domestic alcohol	Labys (1976) U.S.A. (20)
	3.3			Imported alcohol	
	1.0 to 2.0				Labys (1976) Australia (20)
	1.5				Labys (1976) [recalculated by Adrian and Ferguson (1987)] Canada (10,20)

(*continued*)

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Table 2. Continued

Beer	Wine	Spirits	Total/ Absolute Alcohol	Comments	Sources and Jurisdiction
0	0	0.10		Short-term	Johnson and Oksanen (1977)
0	0	0.15		Long-term	Canada (9)
	0.78				Clements and Johnson (1983) Australia (21)
0.23	0.70	0.89		Domestic alcohol	Adrian and Ferguson (1986)
1.54	0.62	0.69		Imported alcohol	Canada (22)
0.96	2.22	0.08		Domestic alcohol dynamic model	Brox, Andrikopoulos and Carvalho (1992)
6.38	6.04	0.83		Imported alcohol dynamic model	Canada (14)

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positive relationship between consumption and at least one measure of traffic safety (as alcohol consumption increased, drunk driving increased), although some also found a negative relationship if a different measure of traffic safety was used. In five studies, reduced availability of alcohol was associated with reduced accidents or traffic fatalities, although not all were statistically significant. Finally, two studies of decreased "economic" availability of alcohol found that banning "happy hour" was associated with fewer drunk driving charges and increasing liquor taxes was associated with a significant reduction in traffic fatalities.

In this latter study (24), analysis of Norwegian data from 1948 to 1979 showed a high positive correlation between alcohol consumption and persons convicted of drunk driving ($r = 0.99$), and between alcohol consumption and drivers killed or injured ($r = 0.93$). This relationship disappeared after controlling for the increase in the number of motor vehicle accidents, or when relating change in alcohol consumption to change in drunk drivers and in drivers killed or injured. Similar results were reported for Danish data from 1930 to 1983.

Analysis of Canadian data for 1978 from the 49 counties in Ontario by one of the authors (25) has shown a positive correlation between alcohol consumption and alcohol offenses (Pearson correlation $= 0.49$, $p = .002$). However, in this study the category alcohol offenses included not only driving while impaired and fail or refuse a breath sample, but also offenses against Liquor Act regulations.

Relationship Between Price of Alcohol and Drunk Driving

Studies of the direct relationship between the price of alcohol and drunk driving have been relatively few in number (Table 3).

Kenkel (15), in his review of the literature on the relationship between the price of alcohol and traffic fatalities, reports that fatality price elasticities range between -0.5 to -1.0. In the case of young adults he reports elasticities of traffic fatalities with respect to the price of alcohol of between -0.7 to -1.6. In particular, he quotes Saffer and Grossman's (26) study of the price of beer which implies traffic fatality elasticities of -0.7 to -1.3 for young drinkers.

Saffer and Grossman (27) consider the effects of drinking age and beer taxes on youth motor vehicle mortality. They use pooled time-series–cross-section data from the 48 contiguous states of the United States (i.e., excluding Alaska and Hawaii, and also the District of Columbia) for the years 1975–81 to estimate equations explaining the motor vehicle death rate for three age groups: 15–17 years, 18–20 years, and 21–24 years. They also estimate an

Table 3. Drunk Driving and Price Elasticities of Alcohol

Beer	Total/ Absolute Alcohol	Dependent Variable Indicator of Drunk Driving	Source and Jurisdiction
	−0.7	Fatalities	Cook (1981) U.S.A. (12)
−0.7 to −1.3		Young drinkers, motor vehicle death rates	Saffer and Grossman (1987) U.S.A. (26)
−0.18 to −0.27		Youth (age 15–24) motor vehicle death rates	Saffer and Grossman (1987) U.S.A. (27)
−0.6 to −0.9		Motor vehicle death rates	Evans, Neville and Graham (1991) U.S.A. (28)
−0.5		Motor vehicle death rates	Chaloupka, Saffer and Grossman (1993) U.S.A. (29)
	−0.74	Drunk driving male	Kenkel (1993)
	−0.81	Drunk driving female	U.S.A. (15)
	−1.25	Drunk driving young male	
	−2.11	Drunk driving young female	
	−0.14	Binge drinkers who drove	Sloan, Reilly and Schenzler (1995) U.S.A. (30)
−0.11		Total vehicle fatality rates	Ruhm (1996)
−0.18		Night-time fatality rates	U.S.A. (31)
−0.17		Total vehicle fatality rates (ages 18–20)	
−0.10		Vehicle fatality rates per miles driven	
	−1.2	Alcohol-involved traffic accidents	Adrian, Ferguson and Her (2000)
	−0.5	Alcohol-involved traffic offenses	Canada (32)

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equation for the minimum legal drinking age, which they treat as endogenous in their fatality equations, on the grounds that state laws setting the minimum drinking age may be influenced by state vehicle mortality rates. Their alcohol price variable is the real tax on beer, calculated as the sum of federal and state excise taxes on a case of 12-ounce containers of beer, deflated by the national Consumer Price Index. They argue that the beer tax is preferable to the full price of beer as an explanatory variable from the statistical point of view since it is unlikely to be determined simultaneously with the mortality rate. They note that the federal excise tax on a case of beer was constant in nominal terms, and therefore declining in real terms, through their data period.

Saffer and Grossman consistently find the real price of beer variable to have a negative and significant effect on motor vehicle accidents for all three age groups. For the 15–17 year age group, the elasticity of motor vehicle fatalities with respect to the price of beer is −0.18, for the 18–20 year group the elasticity is −0.27 and for the 21–24 year age group, it is −0.19, indicating that a 100% increase in the beer tax (whose mean value in their data set, in 1967 dollars, was $0.51 for a case of 24 12-ounce cans of beer) would reduce motor vehicle deaths per hundred thousand population by 18% for the 15–17-year group, by 27% for the 18–20-year group and by 19% for the 21–24-year group (in their data set, mean mortality rates per 100,000 population were 31.6 for the 15–17-age group, 51.5 for the 18–20-age group and 41.9 for the 21–24-age group).

Chaloupka et al. (29) also consider the effect of a range of policies, using data for the 48 contiguous American states for the period 1982–88. They use as dependent variables three different categories of mortality: the total fatality rate, defined as total motor-vehicle fatalities per 100,000 population (sample mean 18.8), the night-driver fatality rate, defined as total driver fatalities between 12:00 midnight and 3:59 AM in motor vehicle accidents per 100,000 population (sample mean 2.3), and the alcohol-involved driver fatality rate, defined as alcohol-involved-driver deaths in motor vehicle accidents per 100,000 population (sample mean 5.9). In addition to these total rates, they consider youth total, night-driver and alcohol-involved-driver fatality rates, defined for the population aged 18–20 years.

Like Saffer and Grossman (26), they use as their alcohol price variable the real (in 1967 dollars) excise tax on a case of 24 12-ounce containers of beer, and they find a negative and significant coefficient on the beer excise tax in all six of their estimated equations, with, as would be expected, the coefficient on beer taxes being larger in absolute value for the more alcohol-involved categories of fatalities. They find that tax increases have a larger effect on fatalities among the younger age groups. They simulate a number of possible policy changes: one involving maintaining the real beer tax at its 1951 level by increasing the excise tax in line with the Consumer Price Index (CPI), another

involving equalizing the beer tax with the tax on alcohol in spirits, and a third in which the beer tax was doubled relative to its sample value.

The first experiment, which in their data set would result in the 1988 tax on a six-pack of beer being 71.6 cents, 16 cents higher than its actual value, they calculated would reduce total fatalities by 11.5%, night-driver fatalities by 23.5%, and alcohol-involved driver fatalities by 26.9%. Among 18–20 year-olds, the same policy would produce reductions of 32.1%, 39.1% and 40.3% respectively.

The second experiment would result in an increase in the 1988 excise tax to 78.4 cents on a six-pack of beer, and would reduce total fatalities by 12.8%, night-driver fatalities by 26% and alcohol-involved driver fatalities by 29.7%, with corresponding reductions of 35.2%, 42.6%, and 43.9% for the 18–20-age group.

Their final experiment, doubling the tax to 32 cents per six-pack, would reduce total fatalities by 3.9%, night-driver fatalities by 8.4% and alcohol-involved driver fatalities by 9.7%, with youth reductions of 11.8%, 14.9% and 15.6%, respectively.

Comparing their estimates of the effects of increases in beer taxes with other possible alcohol-control policies, including raising the minimum legal driving age, they conclude that an increase in the beer tax is the most effective policy for reducing alcohol-related fatalities, matched in effectiveness only by laws requiring a one-year mandatory drivers licence suspension after first Driving Under the Influence of alcohol (DUI) arrest.

Sloan et al. (30) used self-reported data on the frequency of binge drinking and of DUIs from a sample of 49,199 responses from the 1984–90 American Behavioral Risk Factor Surveys. They used alcohol price data produced by the American Chamber of Commerce Research Association, weighting beer, wine, and spirits prices by their respective consumption shares to produce a single alcohol price variable. They found that price increases had a significant negative effect on the probability of binge drinking and on the number of binge episodes conditional on doing any binge drinking. Their results indicated that a 10% increase in the price variable would reduce the expected number of binge episodes per month by 0.09 and that a 10% increase in price would reduce the fraction of binge episodes in which the individual also drove by 1.4%.

Ruhm (31) used 1982–88 data from the 48 contiguous American states to analyze the effects of alcohol prices (and other variables) on measures of vehicle fatality rates per 100,000 population, looking at total vehicle fatality rates, night-time fatality rates, the total vehicle fatality rate for 18–20-year-olds and the vehicle fatality rate per hundred million miles driven. As his price variable he used the tax (measured in constant 1988 dollars) on 24 12-ounce containers of beer. He found that the beer tax had an elasticity of −0.11 in the

preferred equation with total fatalities as the dependent variable, an elasticity of −0.10 in the equation for fatalities per 10,000 miles driven, an elasticity of −0.18 on night-time fatalities, and an elasticity of −0.17 on total young fatalities. He suggested that restoring the real 1988 beer tax to its level of 13 years previously (which would involve a 78% increase) would reduce highway fatalities by 7–8%, saving 3300 to 3700 lives annually.

Cook (12) examined the short-term effect of changes in the liquor tax on the death rate due to auto accidents based on data consisting of 39 observations of U.S. states that had price increases between 1961 and 1975. He found that about two-thirds of states which increased their liquor tax showed a decrease in auto fatalities ($p = .04$, since if alcohol price had no effect, one would have expected half the states to show a decrease and the other half to show an increase in auto fatalities). He found, that on average, a 10% increase in liquor price resulted in a 7% drop in auto fatalities (median price elasticity of −0.7).

In his own study, Kenkel (15) used micro data from the U.S. Health Promotion and Disease Prevention supplement to the 1985 Health Interview survey, which used self-reported information from more than 28,000 respondents on drinking and drunk driving augmented by data on alcohol price, state drunk driving deterrence laws, and alcohol control policies such as knowledge of the health consequences of ''heavy drinking'' or access to alcohol (monopoly sales, closeness to states with lower minimum drinking age, etc.). Controlling for all these extraneous variables, he found that the elasticity of demand of drunk driving with respect to the price of alcohol is −0.74 for males and −0.81 for females, or relatively price inelastic. In the case of young people under the age of 21, the price elasticity for drunk driving is −1.26 for males and −2.11 for females, or relatively price elastic.

Grossman et al. (33) used data from six U.S. national data sets on individuals from 1974 through 1989, and two state-level data sets, for 1975 through 1981 and 1982 through 1988, to examine the relationship between price, alcohol consumption, and drunk driver fatalities. Multiple regression techniques were used to analyze the effects of changes in beer price, taxes and minimum legal drinking ages, while controlling for age, race and parental characteristics, and for determinants of alcohol consumption and fatality, including real income, measures of traffic, roadway and vehicle condition, driver characteristics, religious participation, and fraction of the state population residing in counties prohibiting the sale of alcoholic beverages. Both alcohol use and motor vehicle accident mortality were found to be negatively related to the cost of alcohol. For youth, the incidence of frequent consumption and heavy consumption were negatively related to the price of alcohol. They concluded that, in the United States,

increasing the price of beer by increasing the beer federal excise tax was the most effective way of reducing youth motor vehicle accident mortality, since frequent or heavier drinkers are likely to be responsible for a large percentage of youth motor vehicle crashes and deaths. Through simulation studies, they further found that the effects of a price hike exceeded the effect of increasing the drinking age to 21 in all states.

Simulation studies show that increasing the price of alcohol has a larger effect than increasing the minimum drinking age to 21 on reducing motor vehicle traffic fatalities (33) and drunk driving (15).

The Relationship Between Economic Conditions and Drunk Driving

In addition to the price of alcoholic beverages, a variety of macro-level economic conditions can affect drunk driving. Economic conditions, such as income and unemployment, may affect both alcohol consumption and drunk driving. For instance, an economic downturn accompanied by unemployment may reduce drunk driving by reducing the unemployed's miles driven to go to work or reducing leisure driving to save money when funds are short.

Muller (34) analyzed monthly time series for Oklahoma for the period January 1980 to December 1986 and found that decreasing per capita alcohol consumption and increased unemployment accounted for most of the reduction in motor vehicle fatalities and fatal crashes.

Wagenaar and Streff (35) attempted to develop a complex model to account for the effect of economic conditions on single vehicle night-time fatal crashes taking into account the effect of alcohol consumption. They analyzed monthly time series data on all fatal crashes occurring in the United States between January 1976 and December 1985, and found that economic conditions significantly influenced fatal crash rates both directly and via changes in aggregate amount of alcohol consumed and aggregate amount of driving.

Kenkel (15) controlled for the effect of a variety of demographic variables (age, race, education, marital status) and found that economic variables had an impact on "heavy drinking" and on drunk driving. Unemployment had a significant positive effect on "heavy drinking" in both sexes, including young adults and persons of all ages, and a non-significant effect on drunk driving. Income had a non-significant positive effect on "heavy drinking" in adults of all ages and both sexes, but a significant negative effect on "heavy drinking" of young adults. Income also had significant positive effect on drunk driving in male adults and young adults, but a non-significant negative effect on drunk driving in

female adults and young adults. Working significantly increased "heavy drinking" and drunk driving in adults, and had a positive significant effect in drunk driving in young females, and a positive but not significant effect on "heavy drinking" in young adults and drunk driving in young males.

HYPOTHESES FOR MODELING THE RELATIONSHIP BETWEEN DRUNK DRIVING, PRICE OF ALCOHOL AND OTHER FACTORS IN CANADA

In this analysis, we investigated the relationship between the price of alcohol and drunk driving. First, we considered the link between price of alcohol and alcohol consumption, then the link between alcohol consumption and drunk driving, and then between price of alcohol and drunk driving within the province of Ontario. We hypothesized that in Canada, as in other jurisdictions, we would find a negative relationship between the price of alcohol and alcohol consumption and between the price of alcohol and "heavy drinking." There would be a positive association between alcohol consumption and drunk driving and between "heavy drinking" and drunk driving. Finally, there would be a negative relation between the price of alcohol and drunk driving measures.

Because there are a variety of circumstances other than the price of alcohol that have an effect on drunk driving, they must be taken into account by controlling for their impact when modeling the effect of price of alcohol on drunk driving. We would further hypothesize that after controlling for the effect of these extraneous factors, such as income, proportion of young males in the population, changes in legal drinking age and general trends such as improved roads etc., we would continue to find a negative relationship between the price of alcohol and drunk driving.

Method

We first used graphic analysis and correlation techniques to delineate the basic relationships between price and consumption, "heavy drinking," and drunk driving. Multiple regression techniques were used to model the relationship between price of alcohol and drunk driving controlling for the effect of extraneous factors. We conducted cross-sectional analyses using data for the 49 counties of Ontario for 1989, and

time-series analyses using Ontario provincial annual data for the period 1972 to 1990.

We examined the relation between alcohol consumption and alcohol-involved traffic crashes and alcohol-involved traffic offenses, as well as the relationship between the number of high risk drinkers in the population and alcohol-involved traffic crashes and offenses. Our assumptions were the following:

- Increases in the price of alcohol will reduce drunk driving (we would expect a negative sign on this variable). This variable operates through its impact on alcohol consumption.
- Young males are a high-risk group for both drinking and drunk driving and an increase in their rate will increase drunk driving (positive sign).
- An increase in the minimum legal drinking age will decrease the population at risk of drinking and hence of drunk driving (negative sign).
- Increases in Gross Domestic Product (GDP) can be associated with increased income and employment. It will lead to increased spending on a variety of goods including alcohol, thus increasing alcohol consumption. As more people work there will be more driving to work. As income increases, people will be more likely to be able to afford leisure travel such as going to parties (in which increased drinking may occur) or for weekend jaunts. This may have the effect of increasing drunk driving. On the other hand, people may be too busy working to have time for leisure, which may lead to reduced drunk driving. The generally improved economic conditions may improve overall levels of psychological wellbeing and reduce the level of frustration and other psychological distress, and the tendency to alleviate same through drinking or through going for a long drive, thus reducing drunk driving. Increased levels of employment may increase job-related stress and this may lead to increased drinking as a possible stress-reducing mechanism, thus leading to increased drunk driving. We have no priors for the effect of GDP.

Data

For the cross-sectional analysis, we used data compiled by Statistical Information Services (2) of the Addiction Research Foundation from Statistics Canada's Canadian Centre for Justice Statistics for *alcohol traffic offenses*, and from the Traffic Injury Research Foundation of Canada for

Drinking/Driving Countermeasures Office, Ontario Ministry of the Attorney General (36) for *alcohol traffic accidents*.

Alcohol sales data were used as proxies for *alcohol consumption*. Alcohol sales data were based on data from the Liquor Control Board of Ontario, the Brewers' Retail and from estimates of independent wine store sales (37). Data on price of alcohol were based on information from Statistics Canada (38).

Litres of beverage alcohol from sales data were converted into litres of absolute alcohol using the following average absolute alcohol content values. Spirits were converted at 40% alcohol by volume until 1978 (39), and thereafter consisting of the annual linear interpolation between the 1978 figure and the 1990 figure of 36.9% (40). Beer was converted at 5% alcohol by volume until 1978 (39), and thereafter consisting of the annual linear interpolation between the 1978 figure and the 1990 figure of 4.9% (40). For wine, from 1960 to 1974, conversion factors were as given in Adrian (39; p. 25); from 1974 to 1978 conversion factors were 13%, thereafter consisting of the annual linear interpolation between the 1978 figure and the 1990 figure of 11.7% (40).

Alcohol consumption data served as the basis for the estimated rates of *high risk consumers*, defined as those whose consumption exceeded 35 drinks per week (37,41).

Rates of alcohol consumption were expressed per population aged 15 and older. The rates of high-risk consumers were expressed per 100,000 population aged 15 and over. All other rates are per 100,000 population (42).

Alcohol-involved traffic accidents and offenses were for the calendar year 1989, and consumption data were for the fiscal year 1988–89. These data are described more fully in the section below. Data elements considered in the time-series analysis included data compiled by the Addiction Research Foundation (1,39,43–45).

The dependent variable, drunk driving, was measured as alcohol involved traffic accidents and alcohol involved traffic offenses.

*Alcohol-involved traffic accident*s were measured as the rate per 100,000 population of drivers in alcohol-related traffic crashes resulting in property damage, personal injury or fatalities (46–49).

Alcohol-involved traffic offenses were measured in rates per 100,000 population and included impaired operation of a vehicle causing death or bodily harm, impaired operation of a motor vehicle with over 80 mg% of blood alcohol content, and failing or refusing to provide a breath or blood sample (50; additional data provided by the Canadian Centre for Justice Statistics, Statistics Canada).

Independent variables consisted of price of alcohol, per capita income, the proportion of young males in the population, changes in the legal drinking age, and general trends.

The *price of alcohol* included the price of total alcohol, and the price of beer, wine, and spirits, expressed in real terms, after adjusting for the effect of inflation.

Price of alcohol was measured as the dollar cost of ten litres of absolute alcohol (38,51) as a proportion of personal disposable income (52–54) per person aged 15 and over. This unit of measurement has the effect of correcting for the effect of changes in price due solely to the effect of inflation and further keeps the price constant relative to spending power adjusted for the effect of changes in adult population (defined as those aged 15 and over).

Population figures were provided by Statistics Canada (55–58).

Extraneous independent variables included:

Income data consisted of real per capita income and was based on *Gross Domestic Product* (GDP) at market price (59,60) deflated by the Consumer Price Index (CPI) obtained from the Prices Division of Statistics Canada, and expressed per capita (55–58).

Young males have been shown in other studies to account for a disproportionately high share of drunk driving accidents. Young males in the population consisted of those males aged 15–29 years of age as a proportion of the total population.

To account for the *change in minimum drinking age*, we introduced a dummy variable to take into account the effect of increasing the minimum drinking age from 18 to 19 in 1979. The dummy variable was considered alone and also as an interaction term with two other variables: the male population aged 15–29 as a proportion of the total population, and the price of alcohol.

Statistical analyses of the data were performed on the personal computer (PC) version of SHAZAM (6) versions 6.0 and 7.0, and on PC-GIVE (61) version 7.00.

RESULTS

Cross-sectional Analysis

Our first analysis examined cross-sectional data from the 49 counties of Ontario for 1989. Cross-sectional data showed a positive correlation between alcohol consumption and alcohol-involved traffic crashes

($r = 0.68$, $p < .01$), and between consumption and alcohol-involved traffic offenses ($r = 0.50$, $p < .01$). A positive correlation was also found between rate of high-risk consumers and alcohol crashes ($r = 0.70$, $p < .01$), and high-risk consumers and alcohol offenses ($r = 0.49$, $p < .01$) (5).

Time-Series Analysis

Correlational Analysis

Analysis of Ontario provincial data using time-series for the period 1972 to 1990 found an even stronger correlation between alcohol consumption and both alcohol involved traffic offenses (Figure 4) ($r = 0.89$, $p < .01$) and alcohol involved traffic accidents (Figure 5) ($r = 0.82$, $p < .01$) (5).

There was a positive but not significant relationship between change in alcohol consumption and change in alcohol-involved traffic offenses ($r = 0.42$, N.S.) and alcohol-involved traffic accidents ($r = 0.41$, N.S.) (5).

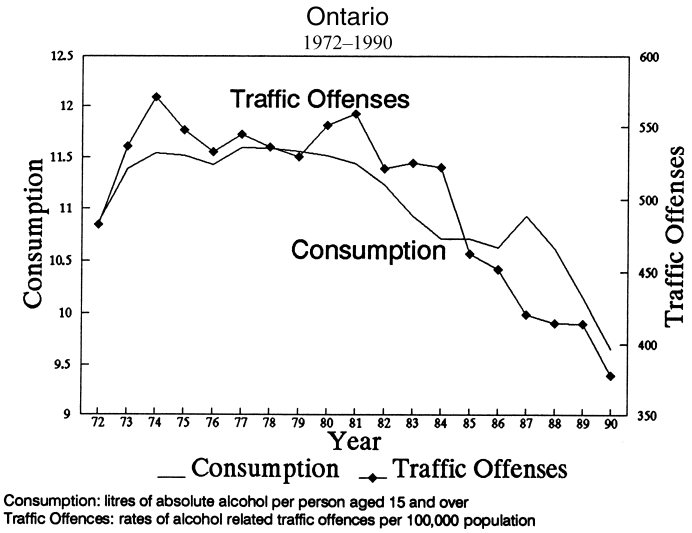

Figure 4. Relationship between the consumption of alcohol and traffic offenses, Ontario, 1972–1990.

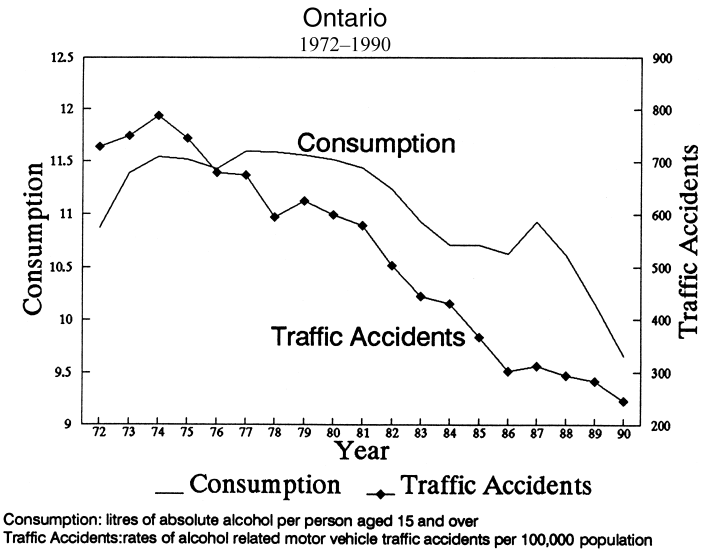

Figure 5. Relationship between the consumption of alcohol and traffic accidents, Ontario, 1972–1990.

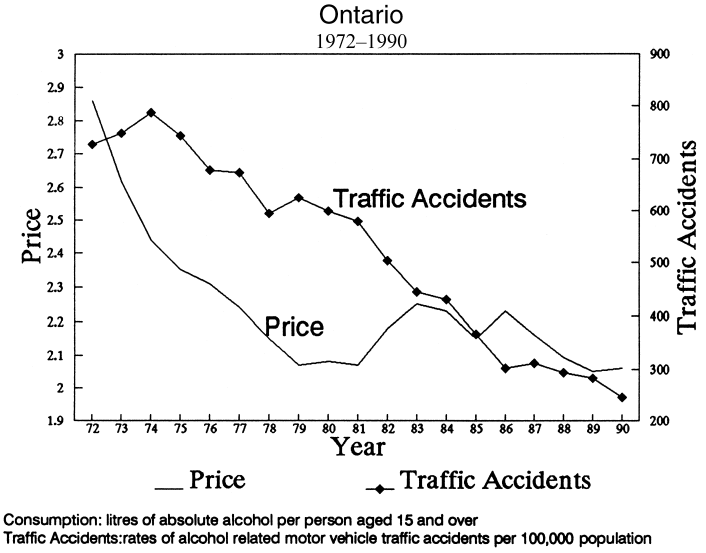

Figure 6. Relationship between price of alcohol and traffic accidents, Ontario, 1972–1990.

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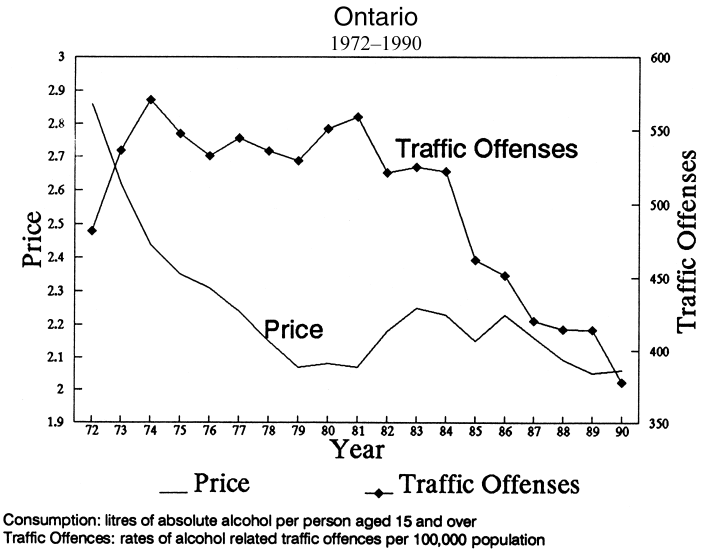

Figure 7. Relationship between price of alcohol and traffic offences, Ontario, 1972–1990.

When we examined the relationship between price of alcohol and drunk driving using Ontario yearly time-series data for the period 1972 to 1990, we found a significant and positive correlation between the price of alcohol and alcohol-involved traffic accidents (Figure 6) ($r = 0.61$, $p < .01$) and a positive but not significant correlation between price and alcohol-involved traffic offenses (Figure 7) ($r = 0.26$, N.S.). However, when we examined the effect of changes in price and changes in accidents and offenses, the correlation was negative and significant for accidents ($r = -0.62$, $p < .01$) and negative and borderline significant for offenses ($r = -0.46$, $.05 < p < .10$ for a two-tailed test) (62).

Multiple Regression Analysis

Finally, we used multiple regression techniques to develop models to examine the relation between drunk driving and price of alcohol, controlling for a variety of other possible confounding factors, including changes in GDP, in the proportion of the population made up of young males (who have been shown in other studies to account for a disproportionately high share of drunk driving accidents), and changes in minimum drinking age.

We also developed a functional form that included variables to account for general trending tendencies as a proxy for a host of other confounding variables.

Many of the variables being used here show trends over time. In analyzing their behaviour it is important to allow for the existence of these trends and to try to separate the general trends of the variables from fluctuations around the trends. There exist a number of different approaches to "pulling out" the effects of general trends. One, which we found to work well in the accidents equation, involves simply including a time-trend variable (TREND) among the explanatory variables, to capture effects of improved roads, greater safety-awareness among drivers, etc.

This yields the following equation for alcohol involved traffic accidents:

1972–1990	Variable	Coefficient	*t*-statistic
Accidents =	Constant	2249.4*	15.32
	Income	0.0112	1.79
	Young males	−55.83	−1.25
	Alcohol price	−227.4*	−3.08
	Trend	−47.75*	−5.05
R-squared = 0.984,	$F(4, 14) = 211.57$**,	DW = 1.55,	

*$p < .05$, **$p < .0001$

Trend is a time-trend variable included to pick up the effect of various excluded factors.

In the equation, the price of alcohol has a significant negative effect on accidents. Income has a non-significant positive effect, and young males have a non-significant negative effect. These effects are presumably operating through the consumption of alcohol. The time-trend is significantly negative, indicating a general tendency to fewer accidents over time. It is significant that we can detect a statistically significant effect of alcohol price on accidents in addition to the general trend. The R-squared and F statistic indicate the general fit of the equation is good.

In the following equation, the real price of all alcoholic beverages has a significant negative effect on alcohol-involved traffic offenses. Income has a significant negative effect, and young males have a significant positive effect. These effects are presumably operating through the consumption of alcohol.

1972–1990	Variable	Coefficient	t-statistic
Offenses =	Constant	329.8	1.36
	Income	−0.009*	−1.97
	young males	33.5*	3.45
	Alcohol price	−97. 1*	−4.00
R-squared = 0.898,	F(3, 15) = 44.15**,	DW = 2.06	

*$p < .05$, **$p < .0001$

The time-trend was not significant in the offenses equations and hence was eliminated from the final equations. The R-squared and F statistic indicate the general fit of the equation is good.

Raising the minimum drinking age to 19 in 1979, whether measured in terms of its effects alone, or in combination with the dummy interaction variables (as an interaction term with the proportion of the population made up of young males or with the price of alcohol), did not have a significant effect on either of our measures of drunk driving. Hence, they were eliminated from the final equations for both accidents and offenses.

Because of multi-colinearity, it was not possible to determine the individual effects of the prices of beer, wine, and spirits.

It was not possible to achieve a satisfactory equation to distinguish between long- vs. short-run effects. The technique used to detect short- vs. long-run effects uses a one-year lag structure which is sensitive to a short-run effect of under a year and a long-run effect of over one year. The technique is not sensitive to short- vs. long-run effects of a period much different from one year. Thus, with the number of observations available to us for this analysis, it was not possible to determine if there were no short- vs. long-run effects in this behaviour, or if the short-run period was of a duration much shorter than one year (e.g., two months) or much over one year (e.g., 1.7 years).

In both the accidents and the offenses equations, our results indicate that price of alcohol does have a significant negative impact on the dependent variables, offenses and accidents, suggesting that alcohol pricing policy can be targeted toward reducing harm from drunk driving.

The size of the effect of changing price of alcohol on reducing drunk driving can be estimated using measures of elasticity. The elasticity of alcohol-related motor vehicle accidents with respect to the price of alcohol was −1.2 or relatively elastic, and the alcohol-related traffic offense price elasticity was relatively inelastic at −0.5.

DISCUSSION

On the whole, our results were in the expected direction. Our study of Ontario cross-sectional data for 1989 found a positive and significant relationship between alcohol consumption and alcohol-involved traffic accidents and alcohol-involved traffic crashes. Our study of Ontario time series data for 1972 to 1990 also found a positive and significant correlation between alcohol consumption and alcohol-involved traffic accidents and crashes whether measured in levels or yearly rate of change.

Analysis of the relation between alcohol price and alcohol-involved traffic accidents and offenses showed a significant negative correlation in their rate of change, as expected.

The positive correlation between price and offenses was not significant, although the correlation between price and accidents was both positive and significant. It is not clear to what this may be attributed and further investigation may be warranted, including, for instance, relating price to type of alcohol-involved traffic accident, i.e., fatal, non-fatal injury, or property damage only accidents.

Because the relationship between price of alcohol and drunk driving appeared to be complex, we did further modeling using econometric multiple regression techniques. After controlling for the effect of confounding factors, we still found a negative and significant relationship between price and accidents and between price and offenses. In addition, we were able to calculate alcohol-involved traffic accident and alcohol-involved traffic offense elasticities with respect to price and the values we found were well within the range reported in other studies in the United States (15).

Changing the Price of Alcohol to Reduce Drunk Driving

One would think that the easiest way to reduce drunk driving would be to increase the price of alcohol. In Canada, taxes make up a considerable amount of the price of alcoholic beverages. According to figures from the Liquor Control Board of Ontario (1989-90), in 1989, the price of a bottle of domestic wine was CAN$6.75. Of this amount, on average, 40% goes to the manufacturer and the remaining 60% goes to the government, consisting of various taxes paid to the federal and provincial governments. The price of a bottle of domestic spirits was CAN$17.75. Of this amount, on average, 17% goes to the manufacturer and 83% goes to the federal and provincial governments in taxes. Because Ontario has a government-controlled monopoly

alcohol sales system, the major beneficiary of such a price rise would be the government. So, the question arises as to why governments do not just raise the price of alcohol. Seemingly, it would reduce drunk driving and give the government more revenue. Unfortunately, the situation is not quite so simple.

One difficulty is that effect of increasing the price of alcoholic beverages is not uniform for each beverage in its impact on the consumption of other alcoholic beverages. Increasing the price of one type of beverage may have the effect of leading consumers to substitute another alcoholic beverage for the one whose price has been increased. Brox et al. (14) have found evidence that, in Canada, increasing the price of domestic spirits leads consumers to increase their consumption of domestic and imported wine, an increase in the price of imported wine shifts consumption to domestic beer, an increase in the price of imported spirits shifts consumption to domestic beer and domestic spirits, and an increase in the price of domestic spirits leads consumers to substitute domestic and imported beer. To complicate matters further, those who have shifted their consumption to domestic wine in response to an increase in the price of domestic spirits are also now likely to consume more imported wine, and domestic and imported beer (Table 4).

Because in Canada taxes account for a large part of the price of alcohol, price changes will often reflect changes in government alcohol tax revenue. Taxes on alcoholic beverages derived from the control and

Table 4. Substitutability and Complementarity of Alcoholic Beverages in Canada

Substitutability	Strong evidence	Domestic spirits	Domestic wine
			Imported wine
		Imported wine	Domestic beer
		Imported spirits	
	Weaker evidence	Imported spirits	Domestic spirits
		Domestic spirits	Domestic beer
			Imported beer
Complementarity	Strong evidence	Domestic wine	Imported wine
			Domestic beer
	Weaker evidence	Imported spirits	Imported wine
			Domestic wine
		Imported spirits	Imported beer
		Domestic wine	
		Imported wine	
		Domestic beer	

Based on reference 14.

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sale of alcoholic beverages are an important source of government revenue. In the fiscal year 1989–90, the governments of all the provinces and territories in Canada raised a total of CAN$3 billion from alcohol, and the federal government raised another CAN$1 billion. Alcohol taxes accounted for between roughly 2% to 4% of *all* government revenue, depending on the jurisdiction (1). If consumption does go down, revenue may also go down. This is because, as price rises, a certain number of people will reduce their consumption, and if they reduce their consumption enough, there is evidence that total government revenue may also be reduced.

Some types of alcoholic beverages are price inelastic, that is to say, as price goes up, consumption does not go down as fast as prices rise. It still goes down, only not so fast as price goes up. As a result, the impact of price changes on consumption may not be so large as one would like it to be from the viewpoint of public health. On the other hand, from the viewpoint of revenue generation, a price increase that does not reduce consumption as much as expected may result in increases in revenue. For those alcoholic beverages which are price elastic, a price increase will reduce consumption more than expected but may also reduce government revenue. So long as alcoholic beverages generate 2% to 4% of all government revenue, there is a limit as to how much governments can afford price increases that decrease consumption but also decrease revenues.

Finding a perfect balance between price increases and tax revenue is a fine art. It has already been shown with tobacco that when taxes are raised so that a package of cigarettes in Canada costs two to three times more than in a neighbouring jurisdiction, whether it be the United States or another province, there develops an active black market trade or smuggling. There is increasing evidence that a similar black market has been developing with alcohol (63), and that governments are considering revising their pricing strategies in consequence (64).

The Social Context

Ways in which price and taxation changes are to be introduced in order to achieve public acceptance depend on social context. In Scandinavian countries public health concerns over the harmful effects of alcohol consumption are used to justify tax and price increases. Until recently, this approach was less likely to be used in Canada, where price increases were usually justified to the public because they were necessary to raise government revenue (the so-called "Sin tax"). When Canadian

governments reduced the tax on tobacco, another addictive substance, it was explained as an economic necessity for small retail corner store owners who were otherwise losing business, especially in border towns in the Ottawa-Hull area where a 5-min walk across a bridge takes one from the province of Ontario to the province of Quebec where cigarettes are CAN$17.00 a carton cheaper. Recently, the public media have alluded to possible public health consequences of such price changes. The public health perspective has gained greater importance in recent years.

Clearly, there is no one simple solution. Because of substitutability between alcoholic beverages in response to price changes (29), raising the price of one class of alcoholic beverages may simply lead consumers to shift their consumption to another class of alcoholic beverage. In order to prevent this, one would need to raise the price of all alcoholic beverages at the same time. Another promising lead is the Phelps (13) study, which found that the drink of choice of young drinkers is beer, that young drinkers have the highest relative risk for drunk driving in comparison to other age groups, and that beer shows the highest price elasticity for youth. Thus, raising the price of beer may have its greatest impact in reducing drunk driving.

It is likely that small incremental steps taken one at a time in the direction that we know can and does work, and working in concert with other measures in the drinking and driving field, may prove useful in reducing drunk driving. Pricing policies are a powerful, although often neglected, mechanism to affect drink driving and more use should be made of these in the traffic safety area.

GLOSSARY

Elasticity: A measure of the responsiveness of the dependent variable to changes in an explanatory variable. Percentage change in the dependent variable divided by percentage change in the explanatory variable.

Price Elasticity: Elasticity of Demand for a commodity with respect to its own price.

Income Elasticity: Elasticity of Demand for a commodity with respect to consumer incomes.

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