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ENDOGENOUS DRINKING AGE LAWS  
AND HIGHWAY MORTALITY RATES  
OF YOUNG DRIVERS

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ABSTRACT

This paper presents estimates of the effects of the drinking age and beer taxes on youth motor vehicle mortality. The data set employed is a time series, from 1975 to 1981, of cross sections of the 48 contiguous states. Separate regressions for 15 to 17 year olds, 18 to 20 year olds and 21 to 24 year olds are presented. A simultaneous estimation model is used to account for the endogeneity of the drinking age. The results show that during the sample period an increase in the drinking age to 21, which is approximately 8 percent, would have reduced mortality in the 18 to 20 year old group by approximately 14 percent. Also a 100 percent increase in the real beer tax, which is approximately \$1.50 per case, would reduce highway mortality of 18 to 20 year olds by about 19 percent. This increase in the beer tax would also reduce mortality by about 8 percent for 15 to 17 year olds and by about 18 percent for the 21 to 24 year olds.

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# Endogenous Drinking Age Laws and Highway Mortality Rates of Young Drivers

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## I. Introduction

In the past few years, there has been an increased public awareness of the potentially adverse effects of alcohol consumption. A major area of concern is alcohol related motor vehicle accidents. In an effort to control alcohol abuse, each state has enacted a variety of regulations governing the sale of alcoholic beverages. Recently, particular attention has been focused on the minimum legal age for purchase and consumption of alcohol. In the early 1970's, these age minimums were lowered in many states. Young drivers, however, tend to be more accident prone than the general population. Concern that the increased availability of alcohol might be exacerbating the already high accident rate among young drivers led to the Federal Uniform Drinking Age Act of 1984. The Act denies a certain percentage of Federal highway construction funds to states that fail to raise their minimum drinking age to 21.

While raising the legal drinking age is an option to deal with alcohol abuse among young drivers, increased taxation of alcohol is another policy that might achieve the same results. This policy tool, however has not been employed. Instead, Federal excise taxes on beer and wine have been fixed, in nominal terms since November 1, 1951. The Federal excise tax on distilled spirits was raised on October 1, 1985. State and local excise taxes have been increased on occasion, but always to raise revenue rather than to discourage consumption.

The purpose of this paper is to estimate the responsiveness of youth

motor vehicle fatality rates to increases in the legal drinking age and to variations in the cost of beer. The focus on young adults is important because motor vehicle accident mortality is the leading cause of death of persons under the age of 35, and the National Highway Traffic Safety Administration (1983) estimates that alcohol is involved in over half of these fatal accidents.

Research on the responsiveness of youth motor vehicle deaths to the to the cost of beer is important because of proposals to increase Federal excise tax rates on all forms of alcoholic beverages.<sup>1</sup> The tax rate on the alcohol in beer is only one third the tax rate of the alcohol in liquor. This has led to proposals to equalize tax rates by increasing beer taxes. Given the popularity of beer among young people and their poor driving records, it is important to obtain estimates of what effect higher beer taxes would have on motor vehicle fatality rates of young drivers.<sup>2</sup>

Estimates of the effect of increased legal drinking ages on motor vehicle fatality rates of young drivers is also important because the Federal Uniform Minimum Drinking Age Act will expire at the end of fiscal 1988. The Insurance Institute for Highway Safety (1985) reports that Texas and Kansas have already adopted laws that will lower the legal drinking age as soon as the Federal penalties end.

There have been a variety of prior studies of the effects of alcohol regulation on motor vehicle accident rates of young drivers. Douglas (1983) provides an extensive review of this literature. There have been few prior studies which estimate the effects of alcohol taxes or prices on highway fatalities. Cook (1981), however, estimates that states that raised their

liquor tax rates had lower motor vehicle deaths of persons of all ages. Most studies of the legal drinking age conclude that increasing the legal drinking age would lower motor vehicle fatality rates of young drivers. For example, Wagenaar (1981), using time series data for the state of Michigan, finds a significant relationship between the drinking age and motor vehicle crashes. Wagenaar's methodology is ideal for estimating short run effects in Michigan. Long run changes and changes in other states, however, cannot be inferred from his study. A somewhat different conclusion is reached by Males(1986). Males concludes that increasing the drinking age only redistributes fatalities to older drivers. Most prior studies of the drinking age employ a univariate methodology. While the simplicity of a univariate methodology has certain advantages, the effect of variations in alcohol taxes and other variables is not controlled.

Three recent studies (McCornac 1982, Cook and Tauchen 1984, Saffer and Grossman 1986) of alcohol regulation and fatality rates of young drivers use multivariate estimation techniques. All three studies also use pooled time series of cross sections for the 48 contiguous states of the U.S. The study by McCornac uses data from 1970 through 1975 and focuses on the death rate of males aged 15 through 24. Data on highway conditions and liquor prices are also included with the drinking age. The study by Cook and Tauchen uses data from 1970 through 1977 and focuses on the death rate of youths aged 18 through 20. Cook and Tauchen employ a set of time and state variables to control other factors influencing highway fatalities. The study by the present authors uses data from 1975 through 1981 and estimates separate fatality regressions for youths 15 to 17, 18 to 20 and 21 to 24.

Data on beer taxes and highway conditions are included with the drinking age. Each study finds a negative relationship between fatalities and the drinking age. The latter study also finds a negative relationship between fatalities and beer taxes.

The research reported here differs from these three prior studies in a variety of ways. McCornac and Cook and Tauchen analyzed a period during which there was a downward trend in the legal drinking age. Between 1970 and 1975, 29 states lowered their drinking ages. Both studies concluded that changes in the drinking age were exogenous to highway fatality rates of young drivers. Exogeneity of the drinking age is not surprising since conformity with the voting age of 18 was the reason given for lowering the drinking age. This study employs a sample period in which 15 states raised their drinking ages. The reason cited for these increases is often concern over motor vehicle fatalities of young drivers. The drinking age should thus be treated as endogenous. This study differs from the earlier study by the present authors in that it employs a two equation simultaneous model to control for endogeneity of the drinking age.

## II. Analytical Framework

The empirical model is derived from a theoretical model consisting of a probability of fatality equation and a demand for alcohol equation. The probability of fatality is determined by alcohol consumption and a set of variables measuring highway conditions and vehicle quality. It is assumed that, on average, alcohol consumption and driving under the influence of alcohol are positively correlated. The demand for alcohol is a function of prices, income and taste. The legal drinking age imposes difficulties or

costs on underaged individuals who try to purchase alcohol. Therefore, as a measure of price, the legal drinking age is included in the demand for alcohol equation. In the probability of fatality equation, alcohol consumption is replaced by its determinants. This results in an equation with prices, the drinking age, income tastes, highway conditions and vehicle quality as determinants. This probability equation is aggregated over age groups in each state and is interpreted as a mortality rate equation.

Estimation of the mortality rate equation is hampered by potential endogeneity of the drinking age. This study uses data from 1975 to 1981, a period when drinking ages were generally increasing. If these increases were motivated by mortality rates associated with the lowered drinking ages of the early 1970's, then the drinking age is endogenous. Endogeneity of the drinking age can be controlled with an econometric framework developed by Maddala (1983). Define the following variables:  $S$  = an unobserved variable measuring sentiment against alcohol;  $S^*$  = an unobserved variable measuring pressure to pass a 21 year old minimum legal drinking age law;  $D$  = the drinking age;  $M$  = highway mortality rates for youths;  $M^*$  = highway mortality rates for youths when  $D$  is not equal to 21;  $X_1$  = a matrix of exogenous variables affecting  $M$ ;  $X_2$  = a matrix of exogenous variables affecting  $S$ . The model can be written as:

$$(1) M = X_1\beta_1 + f_1D + g_1S + \mu_1$$

$$(2) S = X_2\beta_2 + \mu_2$$

where  $\beta_1$ ,  $\beta_2$ ,  $f_1$ ,  $g_1$ , are coefficients and  $\mu_1$  and  $\mu_2$  are error terms.

Equation (1) assumes that mortality is a consequence of exogenous

regressors ( $X_1$ ), the drinking age (D), and sentiment against alcohol (S). The sentiment variable (S), in equation (1), is necessary because such sentiment can have an independent effect on highway mortality rates. In states where sentiment is strongly against alcohol, youths may drink less and thus the state mortality rate may be lower than in states where alcohol is more acceptable. The effect of sentiment on mortality is independent of the drinking age. If states where sentiment is strongly against alcohol have higher drinking ages then exclusion of the sentiment variable will result in an overstatement of the effect of the drinking age. Sentiment is assumed to be a function of exogenous variables such as religion. This relationship is expressed by equation (2).

While sentiment against alcohol may be exogenous, pressure to pass a 21 year old drinking age,  $S^*$ , is not independent of youth mortality. Clearly, increased youth highway fatalities, which are believed to be associated with alcohol, increase pressure to pass a 21 year old drinking age. Exogenous sentiment, S, can also affect pressure to pass the 21 year old drinking age. These relationships are expressed as:

$$(3) S^* = S + \theta M^*$$

The drinking age, D, acts as an indicator of the unobserved variable  $S^*$ .

The relationship between  $S^*$  and D is defined as:

$$\begin{aligned} \text{if } D = 21 \text{ then } & S^* > c_3 \\ \text{if } D = 20 \text{ then } & c_3 \geq S^* > c_2 \\ \text{if } D = 19 \text{ then } & c_2 \geq S^* > c_1 \quad \text{and} \\ \text{if } D = 18 \text{ then } & c_1 \geq S^* \end{aligned}$$

the  $c_1$  are unknown constants with  $c_3 > c_2 > c_1$ . The variable  $M^*$  is the youth highway mortality rate when the drinking age is not 21. The parameter  $\theta$  is a weight. The variable  $S$  has no weight because as an unobserved variable its measurement scale is unknown.

To estimate the model, substitute equation (2) into equation (1) which results in:

$$(4) M = X_1\beta_1 + X_2\beta_2g_1 + f_1D + v_1$$

and substitute equation (1) and (2) into equation (3) to get

$$(5) S^* = X_1\beta_1\theta + X_2\beta_2(1+g_1\theta) + v_2 .$$

The dummy variable,  $D$ , does not appear in equation (5) because pressure to pass a 21 year old drinking age exists only if the drinking age is not 21.

The model can be estimated using a two stage procedure.<sup>3</sup> The first step is the estimation of equation (5) by ordered probit with  $D$  replacing  $S^*$ . Four predicted probabilities result from this procedure. They are, respectively, the probabilities of an 18, 19, 20 and 21 year old drinking age. A new variable  $S^{**}$  is defined as the sum of the four drinking ages weighted by their predicted probabilities. The variable  $S^{**}$  is the expected drinking age and is continuous with upper and lower values of 21 and 18 respectively. The second step is the estimation of equation (4) with  $S^{**}$  replacing  $D$ . Since the mortality rate has a restricted range a logistic specification will conform to the data more closely than a linear specification. The logistic specification is most easily achieved by transforming the mortality rate to  $\ln(M/1-M)$ , where  $\ln$  is the natural logarithm. Maddala

(1983) shows that weighted least squares should be used with this logistic transformation. The weight is:  $[nM/(1-M)]^{1/2}$ , where  $n$  is the age specific population of the state.

The structural model defined by equation (4) and (5) has three important features. First, the exogenous variables are the same in equation (4) and (5). Second, the error terms  $v_1$  and  $v_2$  are correlated. Finally, the variable  $D$  in equation (4) is endogenous.

Equation (4) and (5) are both identified even though identical exogenous variables are used in the two equations and  $v_1$  and  $v_2$  are correlated. Identification results from the use of  $D$  in equation (4) and  $S^*$  in equation (5). Under these conditions equation (4) can be distinguished from any linear combination of equations (4) and (5). Empirically estimation is possible because equation (5) is a nonlinear specification.

### III. Data

The data set is a time series of state cross sections. The time period is 1975 through 1981 and the cross sections include the 48 contiguous states of the U.S.<sup>4</sup> The values and summary definitions of all the variables are show in table 1.

The mortality rate was computed as motor vehicle deaths, by age and state, divided by population, by age and state. Motor vehicle deaths by age and state were provided by the National Highway Traffic Safety Administration and come from unpublished data in the Fatal Accident Reporting System.<sup>5</sup> Deaths pertain to state of occurrence rather than state of residence. Population data by age and state for 1980 were taken from the 1980 Census of Population (Bureau of the Census 1983) and for 1975

from the Area Resource File (Applied Management Sciences 1980). Population data for the remaining years was derived from a logarithmic trend using the 1975 and 1980 data.<sup>6</sup> The mortality rate was computed for all 15 to 17 year old victims, 18 to 20 year old victims and 21 to 24 year old victims.<sup>7</sup>

The legal drinking age variable is the minimum age for the purchase of beer with alcohol content of 3.2 percent or more. These data come from Wagenaar's (1981/1982) compilation of drinking age data.<sup>8</sup> If a state raised its legal drinking age during the year, the drinking age is defined as the age in effect on January 1 of that year.

The beer tax is the sum of the Federal and state excise tax rates on a case of 12 ounce containers of beer divided by the annual national Consumer Price Index (CPI). Deflation by the CPI is required to take account of trends in the prices of other goods between 1975 and 1981. Each regression is estimated with time dummy variables to control trend in the price data and other data. The real beer tax is thus an accurate indicator of the relative price of beer provided the non-tax component of the relative price is not state dependent.

The Federal excise tax on a case of beer was fixed in nominal terms at 64 cents during the sample period. State excise tax rates were obtained from the U.S. Brewers Association (1984). If a state raised its tax during the year rather than on January 1, its tax for the year is computed as a weighted average of the higher and lower rates. The weights are the fraction of the year that each rate was in effect.

The exogenous variables in the  $X_1$  matrix include a border age dummy variable. This variable is equal to one if a state has any bordering state

with a lower drinking age. The border age variable is included because highway mortality for 18 to 20 year olds may increase as a consequence of interstate travel to purchase and consume beer.<sup>9</sup>

Real per capita personal income is also included in the  $X_1$  matrix. This variable should be positively related to the demand for beer, to the quality and condition of motor vehicles, and to safe driving practices. The last relationship emerges because income and schooling levels are positively related. In turn, more educated persons and their offspring are likely to be safer drivers. It follows that the predicted effect of income on the death rate is ambiguous. The income data was published by the Bureau of Economic Analysis.

Three highway measures are included in the regressions. They are the number of vehicle miles traveled in 100,000's of miles per licensed driver, the number of licensed drivers aged 24 years or less as a fraction of the population aged 15 to 24, and a dichotomous variable that identifies states that require compulsory inspection of motor vehicles every year.<sup>10</sup> Similar variables have been used in interstate studies of the determinants of motor vehicle death rates of all age groups by Fuchs and Leveson (1967) and Peltzman (1975). The number of vehicle miles traveled per driver obviously reflects motor vehicle use and it is expected to have a positive regression coefficient. In addition highway driving density probably rises as the number of vehicle miles traveled per driver rises. In general young drivers are more accident prone than older drivers, possibly because the former group has a higher demand for risky driving (Peltzman 1975). Thus, an increase in the per capita number of young drivers should cause the

death rate to increase. States with compulsory motor vehicle inspection programs are expected to have a lower death rate than other states because these programs should result in safer vehicles being operated by the driving public.

The number of licensed drivers of all ages, the number of licensed drivers aged 24 years or less, and the number of vehicle miles traveled were taken from the Federal Highway Administration. The Administration estimates vehicle miles of travel from data on gasoline consumption and motor vehicle registration by state. The compulsory inspection variable was obtained from the Council of State Governments.

The variables in the  $X_2$  matrix are determinants of unobserved exogenous alcohol sentiment. For example, antialcohol sentiment should be relatively widespread in states in which religious groups that oppose the use of alcohol are prevalent. Antialcohol sentiment may also be high in states which a higher than average percentage of the population reside in dry counties. A dry county is one that prohibits the sale of alcoholic beverages.

The variables included in the  $X_2$  matrix are the percentage of the population who are Mormons, Southern Baptists, Catholics and Protestants (excluding Southern Baptists and Mormons). These variables for the years 1971 and 1980 were taken from surveys conducted by the National Council of Churches of Christ and the Glenmary Research Center.<sup>11</sup> Estimates for other years were computed by logarithmic trend. Also included in the  $X_2$  matrix is the percentage of state population that reside in dry counties. These data were obtained from the Distilled Spirits Council of the United States.

#### IV. Results

Column 1 of 2 contains the results for a single equation mortality model for 18 to 20 year olds. Column 2 and 3 of table 2 contain the results for a simultaneous equation mortality model for 18 to 20 year olds. The single equation mortality model assumes that the drinking age is exogenous. This model provides an alternative to the simultaneous model and, by comparison, illustrates the endogeneity bias. The single equation model is estimated using weighted least squares and a logistic transformation of the dependent variable.

The estimation results for the single equation mortality model generally conform to the a priori expectations. The real beer tax and the drinking age are negative and significant as expected. The border age dummy is positive and significant. This suggests that for contiguous states, differences in drinking ages increase youth mortality rates. The income effect is negative suggesting that higher income individuals, or their offspring, are safer drivers and operate motor vehicles that are in better physical condition. An increase in vehicle miles traveled per licensed driver is found to raise mortality. States that require inspection of motor vehicles are found to have lower mortality than other states. Finally the alcohol sentiment variables all have the expected sign and all are significant with the exception of the Southern Baptist variable.

The estimation results for the simultaneous equation models are also presented in table 2. Column (2) contains the results for the mortality equation and column (3) contains the results for the drinking age equation. The two equation model is necessary to control reverse causality

in the drinking age. The empirical verification of this causality assumption is found in the coefficient  $\theta$ , which was described above. The value of  $\theta$  cannot be directly estimated as a regression coefficient but can be estimated by the ratio of the real beer tax coefficient from the drinking age equation divided by the same coefficient from the mortality equation. The value of  $\theta$  is estimated as 8.636. The variance of  $\theta$  was estimated using the change of variable technique and the t value is 6.18.<sup>12</sup> The empirical evidence thus supports the endogeneity assumption and the need for a two equation econometric model.<sup>13</sup>

The coefficients in the single equation model are biased because of correlation of the drinking age with the error term. A comparison of column (1) and column (2) in table (2) illustrates the effect of endogeneity bias. The drinking age coefficient remains negative and significant in the simultaneous model, but the coefficients increase in absolute value. The endogeneity problem also results in bias in the exogenous variable coefficients. Column 2 of table (2) shows that the beer tax remains negative and significant but increases in absolute value. The border age variable and Catholic variables become insignificant when simultaneity is controlled. The Southern Baptist variable is insignificant in both the single equation and simultaneous equation specifications. The coefficients of the highway variables, income, and the exogenous alcohol sentiment variables are somewhat larger in the simultaneous model than in the single equation model.

The results for the drinking age equation are presented in column (3) of table 2. This equation can be interpreted as measuring the pressure to

pass a 21 year old drinking age. The tax, border age, income and highway variables are all included in this equation as indirect measures of mortality. These variables should have the same sign in the drinking age equation as they have in the mortality equation because mortality has a positive causal influence on the pressure to increase the drinking age. The tax, border age and income variable are all significant and, as expected, have the same sign in the drinking age equation as they have in the mortality equation. None of the highway variables is significant. The Catholic and Protestant variables are the only exogenous sentiment variables that are significant. The sign of the Catholic and Protestant variables would be positive if these groups exert political pressure to increase the drinking age. The sign of these variables would be negative if these groups exert pressure on young people not to drink and drive. Since the Catholic and Protestant variables are negative the latter effect must dominate.

Column 4 and 5 of table 2 contain, respectively, the results for simultaneous mortality models for 15 to 17 year olds and 21 to 24 year olds. Both models are specified exactly as the 18 to 20 year old mortality model, with the exception of the dependent variable. The drinking age could affect mortality of 15 to 17 year olds. The probability that an underaged individual can purchase alcohol may increase as the individual approaches the legal drinking age. If underaged individuals who have purchased alcohol, then drive drunk, the drinking age would affect mortality of the 15 to 17 year olds. Since the drinking age is insignificant in the 15 to 17 year old mortality equation, there is no support for this

hypothesis. The drinking age could effect the mortality of 21 to 24 year olds if, as argued by Males (1986), higher drinking ages redistribute fatalities to older age groups. Again the drinking age is insignificant and thus offers no support for this hypothesis. The border age variable is insignificant in both the younger and older age group equations. This result is not surprising since no state allows those under 18 years old to purchase alcohol nor prohibits those over 21 years old from purchasing alcohol. The real beer tax is negative and significant for both age groups. For the younger group, this result may be the consequence of illegal purchases or that members of this group may be with older friends in fatal car accidents. The results for the remaining variables are similar to the results in the 18 to 20 year old mortality equation.

## V. Conclusions

The purpose of this paper was to estimate the effects of the drinking age and beer taxes on youth motor vehicle mortality. The drinking age is assumed to be endogenous in the methodology used to compute these estimates. The econometric results show that mortality has a significant causal effect on the drinking age and that ignoring the problem of endogeneity results in underestimation of the effects of this policy variable.

The final problem to be considered is estimating the effects that exogenous shifts in the two policy variables, the drinking age and the beer tax, will have on youth motor vehicle mortality. The coefficients and means values from the 18 to 20 year old mortality equation can be used to compute elasticities. The elasticity is defined as:  $E = \beta(1-M)\bar{x}$ . The elasticity of mortality with respect to the drinking age is 1.78 and the elasticity

with respect to the real beer tax is .19. An increase in the drinking age to 21, which is approximately 8 percent on average, would reduce mortality in the 18 to 20 year old group by approximately 14 percent. Also a 100 percent increase in the real beer tax (approximately \$1.50 per 24 unit case) would reduce highway mortality of 18 to 20 year olds by about 19 percent. This increase in the beer tax would reduce mortality by about 8 percent for the 15 to 17 year olds and by about 18 percent for the 21 to 24 year olds. In summary, the econometric results show that the drinking age and beer tax both have a significant influence on youth motor vehicle mortality.

Table 1

Definitions and Means of Variables<sup>a</sup>

Variable	Definition, Mean, and Standard Deviation
Motor vehicle death rate	Deaths due to motor vehicle accidents per 100,000 population for the following three age groups: Ages 15-17; mean=31.581. Ages 18-20, mean=51.468. Ages 21-24, mean=41.921.
Real beer tax	Sum of Federal and state excise taxes on a case of 24-twelve ounce cans of beer divided by Consumer Price Index, 1967=1, mean=.518.
Drinking age	Minimum legal age in years for the purchase and consumption of beer, alcoholic content more than 3.2 percent, mean=19.404.
Border age	Dichotomous variable that equals one if a state is a bordering state with a lower drinking age. Mean = .55.
Real per capita personal income	Money per capita personal income divided by Consumer Price Index, 1967=1, expressed in ten thousands of dollars, mean=.3830,
Vehicle miles traveled	Vehicle miles traveled in hundred thousands of miles per licensed driver, mean=.110.
Young drivers	Number of licensed drivers aged 24 or less as a fraction of the population aged 15-24, mean=.726.
Inspection of motor vehicles	Dichotomous variable that equals one if inspection of motor vehicles is required every year, mean=.548.
Mormon	Fraction of population who are Mormons, mean=.012.
Southern Baptist	Fraction of population who are Southern Baptists, mean=.074.
Catholic	Fraction of population who are Catholics, mean=.210.
Protestant	Fraction of population who are Protestants (excludes Southern Baptists and Mormons), mean=.199.
Residents of dry counties	Fraction of the population who reside in dry counties (counties that prohibit the sale of alcoholic beverages), mean = .033.

<sup>a</sup>Data pertain to the 48 contiguous states of the U.S. for the years 1975 through 1981. Means of the death rates are weighted by the age-specific number of persons in the category at issue by state and year. Means of all other variables are weighted by the number of persons aged 15-24 by state and year.

Table 2

Estimated Coefficients<sup>a</sup>

	18-20 Mortality (1)	18-20 Mortality (2)	Drinking Age (3)	15-17 Mortality (4)	21-24 Mortality (5)
Real Beer Tax	-.339 (6.35)	-.374 (5.39)	-3.230 (3.89)	-1.62 (13.15)	-.341 (4.73)
Drinking Age	-.060 (4.68)	-.092 (2.13)	-	.014 (.43)	-.026 (.58)
Border Age	.089 (2.51)	.141 (1.53)	3.061 (11.89)	-.003 (.05)	.080 (.84)
Real Per Capita Personal Income	-2.270 (6.40)	-2.292 (5.66)	-10.909 (4.00)	-2.673 (8.87)	-2.806 (6.66)
Vehicle Miles Traveled	9.191 (11.54)	9.268 (11.56)	-1.457 (.262)	9.149 (15.34)	9.257 (11.09)
Young Drivers	1.202 (10.02)	1.204 (10.59)	-.442 (.378)	1.299 (15.38)	1.297 (10.97)
Inspection of Motor Vehicles	-.039 (1.85)	-.048 (2.27)	-.033 (1.68)	-.043 (2.73)	-.051 (2.35)
Mormon	-.517 (2.82)	-.436 (2.35)	-1.918 (1.263)	-.382 (2.78)	-.760 (3.95)
Southern Baptist	-.209 (.97)	-.104 (.47)	-.923 (.483)	-.065 (.40)	-.083 (.36)
Catholic	-.221 (1.81)	-.225 (1.46)	-4.348 (3.141)	-.184 (1.61)	-.334 (2.09)
Protestant	-.489 (3.59)	-.416 (2.89)	-1.906 (2.004)	-.288 (2.68)	-.874 (5.82)
Residents of Dry Countries	-.592 (4.02)	-.589 (3.95)	-2.157 (1.308)	-.568 (5.13)	-.855 (5.52)
R-squared <sup>b</sup>	.62	.62	.46	.71	.63

<sup>a</sup>The t-values are in parentheses. Each equation also includes an intercept and dichotomous variables for the years 1975 through 1980.

<sup>b</sup>For the drinking age equation,

$$R^2 = 1 - \frac{\log L(A)}{\log L(0)}$$

where log L(A) equals the log likelihood function when maximized with respect to all the parameters and L(0) equals the log likelihood function when maximized with respect to the intercept only.

Footnotes

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<sup>1</sup>For example see Moore and Gerstein (1981), Luks (1983), Cooke (1984), Harris (1984), Becker (1985) and Jacobson and Albion (1985).

<sup>2</sup>Grossman, Coate and Arluck (1986) provide data which indicate that beer is the drink of choice among youths who drink alcoholic beverages. This study also finds no evidence that youths substitute one alcoholic beverage for another in response to price changes. This finding is consistent with those of other studies of the demand for alcoholic beverages. These studies are summarized by Ornstein (1980).

<sup>3</sup>The ordered probit estimation of equation (5) is consistent and efficient. However, in equation (4), since S\*\* replaces D the two step procedure is consistent but not efficient. Amemiya (1979) provides a method for computation of the correct covariance matrix. For notational convenience, let:

$$X = [ X_1 \ X_2 ] \quad (\text{unweighted data})$$

$$L = [ X_1 \ X_2 \ S^{**} ] \quad (\text{weighted data})$$

$$A_1 = [ \beta_1 \ \beta_2 g \ f_1 ]$$

$$A_2 = [ \beta_1 \ \beta_2(1+g\theta) ]$$

$\sigma_1^2$  = estimates variance of  $v_1$

$\sigma_2^2$  = estimated variance of  $v_2$  where  $v_2$  is computed as  $(S^{**} - D)$

$\sigma_{12}$  = estimated covariance of  $v_1$  and  $v_2$

$v_0$  = estimated covariance of  $A_2$  then,

$$\hat{\sigma}_{A1}^2 = (\sigma_1^2 - 2f\sigma_{12})(L'L)^{-1} + (f^2)(\sigma_2^2)(L'L)^{-1}[Xv_0X']L(L'L)^{-1} .$$

Estimation of equation (4) and (5) provides a consistent estimates of  $f$  and data to compute  $\sigma_1^2$ ,  $\sigma_2^2$ , and  $\sigma_{12}$

<sup>4</sup>Alaska and Hawaii were omitted from the data set because several important variables were missing for these two states. The District of Columbia was omitted because it is likely that many of its motor vehicle accidents involve nonresidents.

<sup>5</sup>The Fatal Accident Reporting System is described in detail in NHTSA (1983). Note that NHTSA tabulates alcohol related motor vehicle fatalities. These data were not used because the identification of alcohol related crashes is made by the police based on methods that vary from state to state.

<sup>6</sup>Population estimates for years other than 1980 were adjusted so that the age specific sum for every year coincided with the U.S. total reported by the Bureau of the Census (1982).

<sup>7</sup>Prior studies of the effect of changes in the drinking age have used a variety of mortality measures. These include: (1) nighttime fatal accidents involving youthful drivers; (2) nighttime single vehicle fatal accidents involving youthful drivers; (3) nighttime single vehicle fatal accidents

involving youthful male drivers. Cook and Tauchen point out that these measures are only remotely indicative of total social costs. For this reason the mortality measure chosen includes all fatalities regardless of time of day or number of vehicles.

<sup>8</sup>The legal age for the purchase of beer is very highly correlated with legal age for the purchase of liquor or wine. It is, therefore, not possible to use more than one drinking age variable in the same regression.

<sup>9</sup>Since fatalities are recorded by state of occurrence, this variable will have a positive correlation with mortality if border crossing youths are killed in their own state.

<sup>10</sup>The number of licensed drivers for the years 1976, 1978, and 1980 was obtained by averaging the number of drivers in the preceding and following years.

<sup>11</sup>Jews are included with non-church members in the omitted category because the size of the Jewish population was not reported in the 1971 survey and was significantly underestimated in the 1980 survey.

<sup>12</sup>The value of  $\theta$  can be estimated using any pair of  $X_1$  coefficients from equations (4) and (5). However the only  $X_1$  coefficients that are significant in both equations (4) and (5) are for the tax and income. The income coefficients also resulted in positive and significant estimates of  $\theta$ . To compute the variance of  $\theta$  let  $h_1$  = the real beer tax coefficient in the drinking age equation and  $h_2$  = the real beer tax coefficient in the mortality equation. The variable  $\theta$  is then  $h_1/h_2$ . The variance of  $\theta$  is defined by a Taylor series expansion and is equal to  $\text{var}(h_1) * \left| 1/h_2 \right| + \text{var}(h_2) * \left| h_1/(h_2)^2 \right|$ . The covariance of  $h_1$  and  $h_2$  is assumed to be zero.

<sup>13</sup>Endogeneity of the real beer tax is also possible. However, several variations of a three equation model failed to generate any meaningful evidence of tax endogeneity. The main problem with these models was cross sectional identification of the tax equation.

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