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**THE EFFECTS OF GOVERNMENT REGULATION ON TEENAGE MOTOR
VEHICLE MORTALITY**

City University of New York

PH.D. 1982

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THE EFFECTS OF GOVERNMENT REGULATION
ON TEENAGE MOTOR VEHICLE MORTALITY

by

Dennis C. McCornac

A dissertation submitted to the Graduate Faculty
in Economics in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
The City University of New York.

1982

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DENNIS C. MCCORNAC
1982

This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

THE EFFECTS OF GOVERNMENT REGULATION
ON TEENAGE MOTOR VEHICLE MORTALITY

by

Dennis C. McCornac

Adviser: Professor Michael Grossman

Motor vehicle accidents have long been one of the main causes of death for teenagers in the United States. Generally cited as an important contribution to these mortality statistics is the consumption of alcohol. Too often, however, in an effort to explain changes in mortality rates researchers have focused solely on the role of the minimum legal purchasing age and thus ignored other factors. The purpose of this paper is to fill this gap and examine in a multivariate context, the effect of highway, alcohol, social, and economic factors that contribute to mortality.

Using data for the years 1970-1975, cross-sectional regressions are run for three separate time periods which are termed Period 1, Period 2, and Period 3, for both white

and non-white male and females. The first time period examines the effect of the independent variables on mortality prior to a change in a government regulation affecting the availability of alcohol while the second and third time period analyses examine both the immediate and longer run impact of such legislation. In addition, a pooled time-series cross-section analysis is undertaken for the same groups over the entire period.

The findings of this study indicate that reductions in the minimum legal purchasing age (MPA) have been a major contributor to high motor vehicle mortality rates in those jurisdictions which reduced the MPA during this period. In addition, those areas adjacent to lower MPA states also experience a higher mortality rate. The conclusions of this study indicate that efforts to raise the MPA would not only reduce mortality rates in the states implementing this increase but also would reduce mortality rates in the border states with an existing higher MPA. One potential policy suggestion is that to reduce the overall number of motor vehicle mortalities nationwide for the fifteen to twenty-four year old age group the minimum legal purchasing age be mandated at the national level. The payoffs to such legislation may be substantial.

ACKNOWLEDGEMENTS

Sometimes, one is fortunate enough to meet a person that has a significant impact on his life. I consider myself to be most fortunate of all since I have met not only one, but many. It is hard to put one individual before another, but if this choice must be made the honor would go to Michael Grossman. To attempt to express my gratitude in words would require more pages than the text. His understanding and guidance enabled me to complete this study. Michael Grossman's genuine interest in me as both a student and individual fulfills the essence of an educator and scholar and to this I am most grateful.

I cannot, however, fail to mention the additional members of my examining committee, Linda Edwards and Charlotte Muller. Their extremely helpful and valuable comments were most appreciated. To Thomas Reinwald, who pushed me when I needed it, I shall always be indebted. And to Miriam Langiulli and Sara Nicoll for their fast and efficient typing under tight deadlines.

And finally to my parents, grandmother, and the most important person in my life, Becky, I am thankful for your love, caring and especially your tolerance.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Motor vehicle mortality has long been cited as one of the principal causes of accidental deaths in the United States, accounting for over one-half of all such deaths. (National Safety Council, various issues.) Significantly influencing these statistics is the age of the driver. While comprising less than twenty-three percent of the total licensed driver population, the fifteen to twenty-four year old age group typically accounts for more than one-third of the fatal motor vehicle accident statistics.¹ For this age group, motor vehicle accidents are also the leading cause of death.

The economic cost of teenage motor vehicle mortality is extremely high. The death of an individual contributes to a loss of potential Gross National Product (GNP). The reduction of this mortality rate thus becomes an important issue in public policy. Government regulations have attempted to improve automobile safety through the specification of product design as well as through the implementation of safety policies such as vehicle inspection. The effectiveness of such government action has been examined (Buxbaum and

Colton, 1966; Fuchs and Leveson, 1966; Peltzman, 1975) and is subject to debate. Fuchs and Leveson (1966), in a multivariate study of the relationship between motor vehicle mortality and compulsory vehicle inspection, find that the expected value of the economic benefits of inspection exceed the estimated costs, but by a much smaller differential than previously concluded (Buxbaum and Colton, 1966). Most of the differences in mortality between states with and without inspection are accounted for by the effects of other variables. In a similar light, Sam Peltzman (1975), utilizing a time-series analysis of the effectiveness of legally mandated installation of safety devices on automobiles, suggests that the offsetting effects of the demand for safety without regulation and driver response to the mandatory devices is so complete that regulation has not resulted in a decrease in highway deaths. This conclusion contradicts technological studies that imply large reductions in motor vehicle death rates as a result of such legislation (National Highway Traffic Safety Administration, Annual Reports).

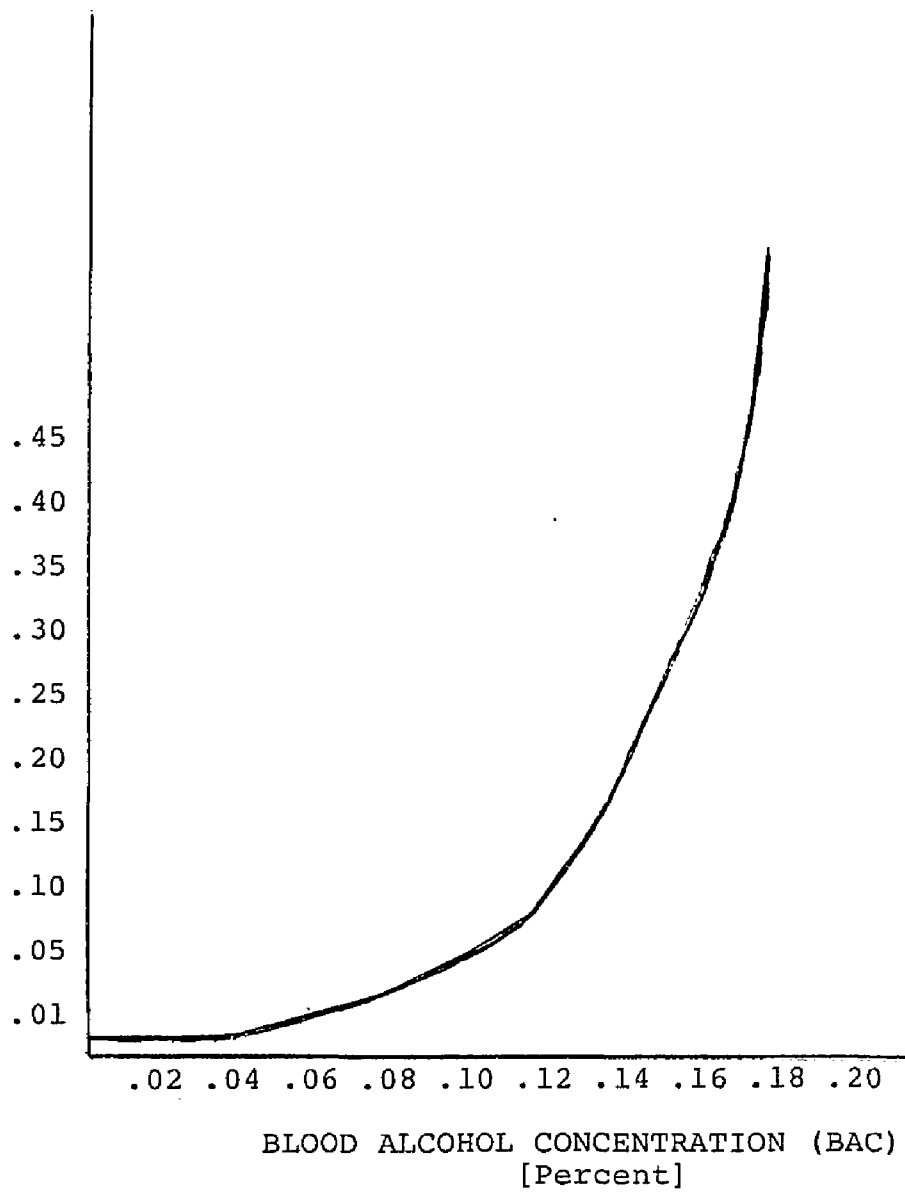
The above studies, while providing estimates of both the benefits and costs of government regulations designed to decrease motor vehicle mortality have examined the population as a whole. Since the 1970's, however, changes in governmental regulations imposed on the consumption of alcohol have been blamed for increasing the motor vehicle mortality rate for a

particular subset of the population, namely teenagers. Thus there is need to examine the effects of government regulations on teenage motor vehicle mortality.

The relationship between alcohol consumption and motor vehicle mortality is well known. Alcohol is the single most important factor yet identified in traffic fatalities (Waller, 1979). The National Safety Council (various issues) estimates that in over one-half of fatal accidents, the presence of alcohol is a contributing factor. In 1981 this represented approximately 27,000 lives (National Safety Council, 1981). The blood alcohol concentration (BAC) found in drivers involved in fatal accidents is generally higher than that of drivers not involved in accidents. A study in the early 1960's, often referred to as the Grand Rapids Study (Borkenstein et al., 1964), examined the relationship between the BAC and the probability of being involved in an accident. This relationship is shown in Figure 1. Above a BAC level of .08 percent, the probability of an accident increases at an increasing rate. Additional studies (Hurst, 1973, Perrine et al., 1971) have obtained similar conclusions.

The age of the driver and the consumption of alcohol together can prove to be a deadly combination. One of the most frequently cited factors contributing to the relationship between youth, alcohol, and mortality rates is the minimum legal purchasing age of alcohol (MPA).

Figure 1
Probability of Causing an Accident



Source: Borkenstein et al.

With the passage of the 26th amendment giving the right to vote to 18 year olds, came the cry for a reduction in the minimum purchasing age. Prior to 1970, only five states granted individuals under the age of 21 the right to purchase alcohol publicly. Beginning in September 1970 when Alaska reduced the MPA from 21 to 19 and continuing to the end of 1975, a reduction in the MPA to 20, 19, or 18 became effective in a total of 25 states (see Table 1).²

The consequence of such legislation, primarily more highway fatalities, soon became a concern. Legislation was introduced in many states to reverse this trend and between 1976 and 1981, 15 states increased the age of legal drinking. At the present time, similar legislation is being considered in New York State.

The reliability of the studies providing estimates of the effects of such legislation is a subject of much controversy. Various studies have obtained differing conclusions as to the consequences of such legislation. One of the earliest studies was undertaken by Robert Hammond (1973) in response to changes in the Michigan law in 1971 that lowered the legal drinking age from 21 to 18. Following the change in the law, statistics reported by the Michigan State police indicated an increase of 119 percent in 1972 for alcohol-related collisions among 18 to 20 year olds. This is contrasted with only a 14 percent increase for all other drivers for the same period. Similar

TABLE 1
States Which Changed Minimum
Legal Purchasing Age During 1970-1975

STATE	1970-71	1972-73	1974-75
	MPA	MPA	MPA
Alabama	21	21	21-19
Alaska	21-19	19	19
Arizona	21	21-19	19
Connecticut	21	21-18	18
Delaware	21	21-20	20
Florida	21	21-20	20
Georgia	21	21-18	18
Hawaii	20	20-18	18
Idaho (a)	21	21-19	19
Iowa	21	21-18	18
Maine	20	20-18	18
Massachusetts	21	21-18	18
Michigan	21	21-18	18
Minnesota	21	21-18	18
Montana	21-19	19-18	18
Nebraska	20	20-19	19
New Hampshire	21	21-18	18
New Jersey	21	21-18	18
Rhode Island	21	21-18	18
Tennessee	21-18	18	18
Texas	21	21-18	18
Vermont	21-18	18	18
West Virginia (a)	21	21-18	18
Wisconsin (a)	21	21-18	18
Wyoming	21	21-19	19

TABLE 1 (contd.)

States in Which the Minimum Legal
Purchasing Age for Alcoholic Beverages was
Constant for the Period 1970-1975*

Arkansas	Mississippi (a)	Oklahoma (b)
California	Missouri	Oregon
Colorado (a)	Nevada	Pennsylvania
Illinois (b)	New Mexico	South Carolina (a)
Indiana	New York	South Dakota (a)
Kansas (a)	North Carolina (a)	Utah
Kentucky	North Dakota	Virginia (a)
Louisiana	Ohio (a)	Washington
Maryland (b)		
	District of Columbia (a)	

* The MPA is 21 for all other states except New York which has an MPA of 18. (Included is the District of Columbia)

(a) Lower MPA for Beer and/or Wine only in 1970

(b) Changed MPA for Beer and/or Wine only during 1970-75

data was reported for both personal injury and fatal collisions as well as for arrests for Driving Under the Influence of Alcohol. This study, however, failed to examine the long-term effect of MPA legislation. Subsequent research by the Michigan Council on Alcohol Problems (MICAP RECAP, 1973) examining both prior and post law-change periods over a three year time span reported that for the time period immediately succeeding the law change there was a significant increase in alcohol-related collisions. However, the long run effect was much less significant with collisions returning to a level consistent with the trend.

Cucchiaro et al. (1974) conducted an investigation of the effects of a lower MPA on a single state, Massachusetts. Prior to March, 1973 when the MPA was reduced to 18, the legal age was 21. Using monthly data for the period January, 1969 to September 1973, analyses were performed for three types of collisions and for four driver age groups: under 18, 18-20, 21 to 23, and 24 and over, as well as for all driver ages combined. In those cases in which alcohol is determined to be a contributing factor (based on certain criteria in the study) significant increases in collisions are reported for the following categories following the change in the law: total alcohol-related fatal collisions; total alcohol-related property damage collisions; and total fatalities among 18-20 year olds. For the older age group, no increases are found

for total alcohol-related personal injury collisions, total fatal collisions, and fatalities. The results support the contention that a lowering of the minimum purchasing age does contribute significantly to alcohol-related collisions involving the under 21 year old driver. Increases ranged from 24 percent for property damage collisions to 75 percent for fatal crashes.

The validity of the conclusions reached in various studies has been subject to debate. Zylman (1975) argues that the increase in the number of young drivers involved in collisions as reported by Hammond (1973) could have resulted from either (1) an increase in police surveillance of the younger age driver, (2) year to year fluctuations in the mortality figures, or (3) to a change in drinking and driving practices of young people that were unrelated to any changes in legislation. Paul Whitehead (1977) in defense of the study by Hammond and MICAP provides support for the hypothesis that changes in law had an effect on collision involvement though he notes that the use of extended time series would have been more desirable. The desirability of a long-run analysis can also be applied to the study by Cucchiaro et al. (1977).

One of the most comprehensive studies was conducted by Richard Douglass (Ph.D. diss. 1974: Douglass and Filkins, 1974) for the National Highway Traffic Safety Administration.

The objective of his dissertation research was twofold:

(1) to determine if alcohol-related highway crashes increased among legally affected populations of drivers in three study states and (2) given that changes were found in the frequencies and rates of alcohol-related crashes to determine whether a causal relationship exists between the crash experiences and the legal changes. Using a multiple time series, quasi-experimental design data were collected from seven states. These seven states were primarily chosen for their specific drinking law characteristics. Four of the states had not changed their drinking laws for many years; the first two (New York, and Louisiana) had a MPA of 18 years old and the other two (Pennsylvania and Texas) had a MPA of 21 years old. The three other states, Michigan, Maine and Vermont, all of which changed their drinking laws within a six month period in 1972, were used as examples of transitional states.

The dependent variable used to measure changes in alcohol-related crashes was a three-factor surrogate variable consisting of the key alcohol-related descriptive variables that were most likely to predict driver crash involvement. The development of such a variable became necessary due to inconsistent reporting and measurement of alcohol involvement in motor vehicle accidents both over time and between states. The results of an analytic program called "automatic interaction detection," (AID) designed to construct the dependent variable

revealed that male drivers driving late at night were consistently (53 percent to 63 percent) involved in single vehicle alcohol-related crashes.

Utilizing this surrogate to compare frequencies of accidents it was found that statistically and socially significant increases in alcohol-related crashes resulted in Michigan and Maine following the effective dates of the 18-year-old legal drinking ages. No concomitant changes were found in Vermont, a transitional state, or in any of the four control states (Douglass, 1974).

Subsequent research was also undertaken to investigate the problem of alcohol, speed, and the age of the driver. In a report prepared for the United States Department of Transportation (Fingerman et al., 1977), an empirical analysis was conducted to determine the joint influence of slightly excessive speed and low-to-moderate blood alcohol concentration of alcohol upon accident-involvement as a function of age and driving experience. Data on a sample of 7,354 drivers involved in accidents in North Carolina in 1974 were cross-tabulated to produce a series of contingency tables. Log-linear analyses were conducted to obtain orthogonal estimates of the relationships among drinking, speeding, age, and experience. The conclusion of this study revealed that accident-involved drivers who were judged to have been drinking and were suspected of a speeding violation did have

a significantly higher number of accidents than expected relative to accident-involved drivers who had been drinking but not speeding, speeding but not drinking, or neither. With regard to the interactions of drinking and speeding violations with age, the results revealed that the speeding-drinking problem is not a special problem of young drivers. For older as well as younger drivers, a higher than normal accident rate occurred at speed above 46 m.p.h. when drinking was involved.

The recommendation of the authors suggest that further study of the relationship between drinking and the age of the driver is warranted since it may lead to improved alcohol countermeasures targeted at particular age segments of the driving population.

The most recent research on the effects of the minimum legal purchasing age and traffic accident involvement of young drivers was reported by Alexander Wagenaar (1981). Approaching the problem somewhat differently than previous studies, Wagenaar investigated the effects of a rise in the MPA by two states (Michigan and Maine) in response to the negative consequences of a lowered MPA reported previously. The study evaluated the effects of returning to the higher drinking ages that existed in the early 1970's, and to determine whether the raised drinking age reversed the effects of the lowered age, and whether the effects of

the legal change varied across crash severity categories.

Similar in design to previous studies (Douglass, 1974; Cucchiaro et al., 1974) states in which legal changes occurred were compared to states with no change in the legal law. Within each state comparisons were made between young drivers directly affected by the drinking age change and their proximal peers not the focus of the legal change.

The conclusions of the Wagenaar (1981) study indicated that the imposition of higher legal drinking ages reduced alcohol-related crash involvement among young drivers in both Maine and Michigan. Therefore, a return to the higher drinking age may be an effective countermeasure to reduce alcohol-related accidents. Wagenaar does note, however, that before such recommendations are made, increased research is necessary to evaluate the effect of differing legal ages between states.

Barsby and Marshall (1977) in a multiple regression analysis on the consumption of distilled spirits revealed that short-term increases in the level of consumption after reductions in the minimum legal purchasing age were not statistically significant. Thus they conclude that legislation proposals to reverse the reductions in the MPA on the justification that it would reduce economic and social damages rests on tenuous grounds. "It is possible that we only perceive increases in misuse

because of a heightening awareness of alcohol problems in general (unrelated to reductions in the MPA), and because especially intense searches for potential misuse may be conducted when the MPA is reduced." (Barsby and Marshall [1977], p. 1678). These findings, however, may be a result of the use of data on alcohol consumption on the entire population and not on the specific teenage and young adult group.

In reviewing the literature on the relationship between changes in the minimum purchasing age and motor vehicle mortality rates, one underlying problem exists. This problem, noted by Williams et al. (1975) but never fully examined, is that changes in motor vehicle mortality cannot be attributed to one specific factor, such as the minimum purchasing age, until alternative explanations are ruled out. Fluctuations in highway safety measures, travel characteristics, and social and economic indicators all may influence the mortality rates. In addition, factors other than the minimum purchasing age will affect the amount of alcohol consumption.

The objective of this paper is to fill the gap left by previous studies by investigating empirically factors which affect teenage motor vehicle mortality rates. By utilizing data for the time period 1970 to 1975, both a time-series and cross-sectional analysis are undertaken.

Multivariate equations are estimated for (1) three time periods in order to examine and compare the before, immediate, and longer run (one-year) impact of changes in relevant variables on mortality rates and (2) the entire time period in order to examine the effects of the relevant variables over time by exploiting the pooled time-series cross-sectional aspect.

Many of these variables used to explain variations in mortality rates in this study result from government regulations, but some are exogenous to governmental action. By controlling for those exogenous variables, the research in this paper will provide unbiased estimates of the effectiveness of government regulations. As such, it will be a valuable tool for government policy makers in their efforts to reduce motor vehicle mortality rates.

Footnotes

1. The total number of licensed drivers in the United States was 125,426,582. For the 15-24 age group the number was 28,186,104. A state-by-state breakdown is presented in any edition of Highway Statistics.
2. The minimum legal purchasing age is defined for the purchase of distilled spirits only.

CHAPTER II

ANALYTICAL FRAMEWORK

One of the goals of public policy is to achieve the most efficient allocation possible. The use of economic theory can provide many insights into the behavior of individuals that are beneficial to the decision-making process. One of the basic propositions in economics is that the amount of a good consumed depends on the amount of resources available (income and wealth) and the price of the good. The true cost or real price of a good includes not only the nominal price, but also the costs incurred to obtain and consume it. In addition, the preferences of the individual have a significant impact on the choices made.

In the case of alcohol, individuals are not totally free to choose their optimal consumption levels because of government regulations. The levying of excise taxes, the licensing of outlets allowed to dispense alcohol, and the setting of minimum legal drinking ages all provide powerful tools to control the level of alcohol consumption. And examination of the effectiveness of government policies designed to curb alcohol consumption and/or abuse will in turn provide an insight into the effectiveness of government regulations in reducing teenage vehicle mortality rates.

Before proceeding in the analysis, a brief discussion of the theoretical underpinnings of the model will provide a clearer insight into the empirical specifications.

Theoretical Model

The individual is concerned with the present period which he is certain to survive, and one future period which he will survive with some probability. His expected utility is given as:

$$(1) \quad E(U) = U(C_1, A) + (1 - D)U(C_2)$$

where $E(U)$ is expected lifetime utility; $U(C_1, A)$ is period 1 utility which depends on period 1 consumption of all other goods except alcohol (C_1) and the consumption of alcohol in period 1 (A). $(1-D)$ is the probability of survival to period 2. Thus D is the probability of not surviving or the probability of mortality. $U(C_2)$ is the utility of period 2 consumption of all goods including alcohol. Alcohol is not separated out here because the analysis is concerned with the effect of the consumption of alcohol in period 1 only. If the level of alcohol consumption is greater than zero in period 1, the consumer faces a probability (D) of mortality. The level of alcohol consumption directly affects the probability of mortality as was shown

in the preceding section in Figure 1. As Figure 1 indicates, the mortality probability is greater than zero at a level of alcohol consumption of zero. This takes into consideration the effect of highway, health, and other exogenous factors that contribute to mortality. The probability function thus takes the form of a production function for mortality (D). The level of alcohol consumption is a choice variable which for the individual affects the probability of mortality. Letting the effect of highway and other exogenous factors in the production function be equal to H, the production function for mortality is:

$$(2) \quad D = (A; H)$$

where $D_A > 0$, $D_{AA} > 0$ when $A < A'$, $D_{AA} < 0$

when $A > A'$ since D has an upper limit of one.¹

Alcohol consumption (A) affects lifetime expected utility in two ways: (1) an effect on period 1 utility via A, which enters directly in equation 1, (2) and an effect on the probability D, that the individual will not survive to period 2. Assuming individuals possess no nonhuman assets, the budget constraint is:

$$(3) \quad C_1 + pA + C_2/(1 + i) = WT + (WT/[1 + i])$$

where the left-hand side is the present value of expenditures on alcohol and other consumption, and the right-hand side is the present value of labor earnings. In equation 3, p is the cost of alcohol, i is the rate of return on nonhuman capital, W is the individual market value of time and T is total time in a period.

The individual chooses the levels of A , C_1 , and C_2 to maximize expected lifetime utility subject to the budget constraint. Maximizing the Lagrangian expression,

$$(4) L = U(C_1, A) + (1 - D)U(C_2) + \lambda(S - [C_1 + pA + C_2/(1 + i)])$$

where λ is a Lagrange multiplier ($\lambda < 0$) and S represents full income, the first order conditions are:

$$(5) \frac{\partial L}{\partial A} = U_A - D_A U(C_2) - \lambda p = 0$$

$$(6) \frac{\partial L}{\partial C_1} = U_{C_1} - \lambda = 0$$

$$(7) \frac{\partial L}{\partial C_2} = (1 - D)U_{C_2} - \lambda/(1 + i) = 0$$

The condition of interest in this paper is that for alcohol consumption. The following conclusion is obtained. The value of marginal product in producing mortality or the marginal cost of alcohol consumption is equal to the value of marginal benefit of alcohol consumption.

$$(8) D_A V = B \quad \text{where}$$

$$(9) V = U(C_2)/\lambda \quad \text{and}$$

$$(10) B = U_A/\lambda - p$$

In equation 8, D_A is the change in the probability of mortality due to a change in alcohol consumption. V is the monetary worth to the individual of his future utility from period 2 consumption (shown in equation 9). The value of marginal product of producing mortality is the value of the change (increase) in the probability of mortality as a result of an increase in alcohol consumption, *ceteris paribus*. The value of marginal benefit (equation 10) is the monetary value of marginal utility of alcohol consumption minus the dollar cost (p).

This equilibrium condition determines the optimal amount of alcohol consumption, A^* . Holding constant the value of marginal product of producing mortality curve ($D_A V$), a decrease in the marginal benefit of alcohol consumption will shift the value of marginal benefit curve ($U_A/\lambda - p$) to the left causing a decrease in A^* . An increase in the dollar cost (p) will decrease A^* and a decrease in the monetary value of the utility of alcohol consumption (U_A/λ) will decrease A^* . Holding constant the value of marginal benefit curve, anything which increases the value of marginal product of producing mortality will shift the curve ($D_A V$) to the left. An increase in H in the production function for mortality (equation 2), *ceteris paribus*, will increase D at each level of A resulting in a decrease in A^* and an increase in V will decrease A^* . The value of V will change

as a result of changes in i , W and T , as well as by taste parameters.

As shown, the level of utility depends on the consumption of alcohol, other goods, and the mortality probability. The probability of mortality is determined by the level of alcohol consumption and as well as by various other inputs such as highway safety laws, licensing of drivers, educational levels, and related social characteristics.

The above model provides a useful setting within which to view the level of alcohol consumption, but empirical estimation of the demand for alcohol would not yield answers to the questions posed in the introduction. Such estimates would only yield information about the impact of price and availability variables on alcohol use. To determine the effect of government regulations on the teenage motor vehicle mortality rate, estimates of the production function for mortality are needed. To determine whether different sex and race groups are more "efficient" at producing mortality also requires estimates of this production function.

Mortality Production Function

A simple linear production for mortality is represented by:

$$(11) D = a_0 + a_1A + a_2H + a_3F + u$$

A is the level of alcohol consumption, H is a vector of highway variables (rural-urban highway mix, highway travel

density, gasoline consumption, driver's license age, and vehicle inspection requirement), F is a vector of social and economic indicators (educational level, health care, and unemployment) and u is a random error term with the usual properties.

The production function above cannot be estimated exactly as stated because it is difficult to measure all the alcohol consumption inputs. The alcohol demand function depends on the following set of variables:

$$(12) \quad A = b_0 + b_1P + b_2C + b_3I + v.$$

P is actual price, C is a vector of availability factors (minimum legal purchasing age, type of state control, number of establishments, border state price difference and border state age difference), I is personal income, and v is a random error term with the usual properties. Substituting equation 12 into equation 11 yields estimates of the total impact of both policy and non-policy variables on teenage motor vehicle mortality. The reduced form equation actually estimated is:

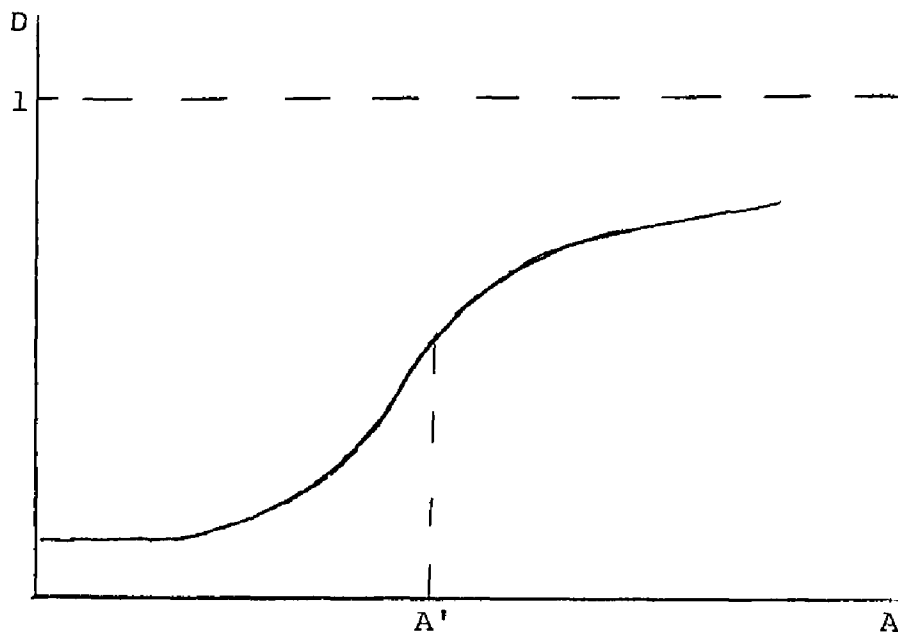
$$(13) \quad D = a_0 + a_1b_0 + a_1b_1P + a_1b_2C + a_1b_3I + a_2H + a_3F + a_1u + u$$

The starting point for the empirical work in this paper is the interest in the policy manipulable variables; the minimum drinking age, the minimum driving age, the price of liquor and its availability, etcetera, on teenage

motor vehicle mortality. Therefore, the empirical work will provide estimates of the effects of these variables on teenage mortality, and in particular, of (a_1, b_1) , (a_1, b_2) , (a_1, b_3) , a_2 and a_3 .

Footnotes

1. This point is illustrated graphically below:



D = probability of mortality

A = level of alcohol consumption

A' = point of inflection

$D_{AA} > 0$ from 0 to A' , $D_{AA} < 0$ beyond value of A' , where D_A is the first derivative of D . D_{AA} is the second derivative.

CHAPTER III

EMPIRICAL IMPLEMENTATION

Data sources for this study are the Enhanced Mortality Files, the Liquor Handbook, Highway Statistics, the Area Resource File, as well as additional statistical publications. The number of deaths per county, classified by age, sex, and race for the years 1970 through 1975 are obtained from the National Center of Health Statistics Enhanced Mortality Files. Information on liquor prices and availability are taken from the relevant issues of the Liquor Handbook. The Liquor Handbook is an annual publication of the Gavin-Jobson Company designed to provide marketing information on the distilled spirits industry. The specific source of each variable is contained in Table 2.

The empirical analysis is limited to the fifteen to twenty-four year old age group. The total number of deaths per county for this age group by race and sex has been aggregated to the state level. The total state number of deaths is divided by the total state population (also aggregated from the county level by race and sex) to obtain the motor vehicle mortality rate. The unavailability of many of the independent variables at the county level limited

the unit of observation to the state. The motor vehicle mortality rate is defined as the number of deaths per 1,000 population per year for this age group. Separate regressions are fitted for both white and non-white male death rates as well as for white and non-white female death rates. Male death rates are significantly larger than female death rates for both race groups. In addition, the percentage of non-white persons may be highly correlated with other independent variables since the independent variables are not race-specific. Preliminary results revealed significant race differences in slope coefficients so that pooling whites and non-whites for estimation was inappropriate.¹ In fitting race-specific regressions, the degree of multicollinearity is reduced and the coefficients of the independent variables are allowed to vary between races.²

The linear regressions are estimated on both a weighted and non-weighted basis. Since the unit of observation is the state the problem of heteroscedasticity may arise due to the various size of state populations. The weight used is the square root of the race and sex specific population.

The time period chosen is the years 1970 through 1975. This was done for two primary reasons. The first is that data are readily available from all sources for this time period. The second and most important reason is that

it will enable information to be provided on the coefficients in the cross-section on a time-specific basis as well as over time.

During the period 1970-1975, an important change occurred in one of the independent variables commonly believed to have a significant impact on the motor vehicle mortality rate for this specific age group. As discussed earlier, between 1970 and 1975, many states reduced the minimum purchasing age to below 21 for distilled spirits. Though some studies (Barsby and Marshall, 1977) have argued that a lower MPA has not resulted in any significant increases in alcohol consumption immediately after a change in the law (and thus possibly increased mortality rates) the effect of such changes in a longer run has not been examined. Therefore, to control for both the immediate and longer run (after one year) effects the period 1970-1975 has been broken down into three separate time periods: 1970-71, 1972-73, 1974-75 which are termed Period 1, Period 2, and Period 3, respectively.

The first period, Period 1, is that period prior to changes in the minimum legal purchasing age. Prior to this period, changes in drinking ages had not occurred since the repeal of Prohibition. It should be noted, however, that three states (Alaska 1970, and Vermont, Tennessee and Montana 1971) reduced their MPA's during this period.

During the second period, Period 2, twenty-one states lowered the minimum purchasing age (12 in 1972 and 9 in 1973).

These substantial cross-sectional variations in one of the independent variables may affect the dependent variable in a number of ways. If a lowered MPA results in increased frequency and amount of consumption, mortality rates could possibly be affected. However, if behavior is slow to react to changes in the variables, the effects will not show until a later time period. The analysis in this period will examine any immediate effects of changes in the MPA as well as serve as a comparison to the findings of previous studies.

In the third period, Period 3, only Alabama (1975) changed the MPA. The results obtained from the cross-sectional regression analysis in this period will provide estimates of possible changes in the coefficients after reduced MPA's have been in existence for at least one year.

Another important reason for choosing the period 1970-1975 is that other changes occurred which will affect the variables. In 1973-1974 the first Arab embargo of oil products to the United States was implemented. This resulted in a rapid rise in the price of gasoline. In addition, the 55 mile speed limit was imposed. Both these changes have affected the driving habits of the population in general and consequently mortality rates. The breakdown of the analysis into distinct time periods serves to control for these variations.

Observations are obtained from forty-nine of the fifty states plus the District of Columbia. The state of

Wyoming was dropped from the analysis due to problems in measurement of the number of mortalities for three of the six years of the relevant time period. In order to maintain consistency in the data from the original source, the observations from Wyoming were omitted.⁴ The final sample size in the cross-section is 50. For the pooled time-series cross-sectional analysis the number of observations for each race-sex group is 150. This consists of the fifty separate cross-section observations over three distinct time periods.

The dependent variable is a two-year average of the race-specific mortality rate (MRWM, MRWF, MROM, MROF). The independent variables are also two-year averages, whenever possible. Two-year averages were taken to attenuate random elements in the variables that were obtained at the state level. Table 2 contains definitions, means and standard deviations for all the dependent and independent variables classified by race and sex for both the cross-section and pooled time-series cross-section. The headings indicate how these variables relate to the theoretical factors appearing in equations 10 and 11.

TABLE 2
Definition of Variables

Variable Name	Source ^a	Definition	^b Mean, Standard Deviation							
			1970-71		1972-73		1973-74		1970-75	
<u>Dependent Variables</u>										
MRWM	1,2	Number of motor-vehicle mortalities per 1,000 population per year for 15-24 year old age group.	.8125 (.7932) ^c	.246 (.203)	.7964 (.7879)	.215 (.183)	.6798 (.6677)	.148 (.125)	.7629 (.7589)	.214 (.191)
MROM	1,2	MR = mortality rate W = white race O = non-white race	.8692 (.7178)	.710 (.513)	.8653 (.6614)	.894 (.600)	.6025 (.3734)	.752 (.494)	.7790 (.7402)	.794 (.741)
MRWF	1,2	M = male F = female	.2441 (.2385)	.076 (.063)	.2428 (.2381)	.074 (.062)	.1993 (.1921)	.057 (.049)	.2261 (.2256)	.072 (.066)
MROF	1,2		.2837 (.2063)	.357 (.226)	.3468 (.2119)	.438 (.262)	.2119 (.1344)	.272 (.168)	.2808 (.2481)	.364 (.346)
<u>Availability Variables</u>										
LIQPR	3	Price including tax of four-fifth quart of Seagram 7 Crown deflated by state-specific C.P.I. (in dollars).	4.383	.499	4.149	.504	3.572	.437	4.032	.586
BEPR	4	Tax rate on case of 24 twelve ounce cans of beer deflated by state specific C.P.I. (in dollars).	.341	.341	.318	.309	.266	.259	.311	.025
WINPR	4	Tax rate on gallon of table wine deflated by state specific C.P.I. (in dollars).	.438	.054	.446	.049	.356	.040	.413	.028

TABLE 2 (contd.)

Variable Name	Source	Definition	Mean, Standard Deviation							
			1970-71		1972-73		1974-75		1970-75	
NLIS	3	Number of on, off or on and off premise licenses to sell liquor per capita.	1.515	.715	1.178	.71	1.25	.77	1.193	.726
AGE	3	Minimum legal purchasing age of alcohol (in years).	20.76	.654	20.03	1.134	19.61	1.433	20.131	1.21
TYPCON	3	Dummy variable that equals one if state is a license state (sale of liquor by private stores).	.660	.479	.660	.479	.660	.479	.660	.479
APDR	See text	Difference of price of alcohol in given state and border state price times percentage of population that live in counties that border given state. Value of zero if border state age or price higher. Deflated by C.P.I. (in dollars).	.006	.020	.0076	.019	.019	.027	.0072	.022
AMD	See text	Difference of given state MPA and border state MPA if border age lower times percentage of population that lives in counties that border given state (in years).	.239	.485	.247	.464	.225	.492	.236	.477

TABLE 2 (contd.)

Variable Name	Source	Definition	Mean, Standard Deviation							
			1970-71		1972-73		1974-75		1970-75	
<u>Highway Variables</u>										
GCPC	7	Number of gallons of gasoline consumed per capita per year by state (in hundreds).	447.18	66.01	489.42	75.64	477.21	69.55	471.27	72.27
DL	7	Age at which youth is able to obtain drivers license (in years).	16.60	.70	16.60	.70	16.60	.70	16.60	.70
MUNHT	7	Number of vehicle miles traveled per mile of municipal highway (in millions).	2034.66	813.87	2235.19	944.16	2328.89	1113.96	2199.58	966.55
RURHT	7	Number of vehicle miles traveled per mile of rural highway (in millions).	621.59	954.38	714.60	1129.33	297.49	1012.27	677.80	1028.39
INSP	4	Dummy variable that equals one if state requires vehicle inspection.	.60	.495	.60	.495	.60	.495	.60	.495
URR	4	Number of miles of municipal highway miles per number of miles of rural highway.	.382	.78	.409	.868	.364	.730	.385	.788

TABLE 2 (contd.)

Variable Name		Source	Mean, Standard Deviation							
Social and Economic Variables			1970-71		1972-73		1974-75		1970-75	
INCR	5	Per capita personal income per year deflated by C.P.I. (in dollars).	3334.76	363.38	3664.29	377.71	3365.67	356.25	3554.90	395.57
HOSP	2	Number of hospitals per capita.	.0487	.062	.0474	.060	.0464	.060	.0598	.08
WME	6	Medium number of years of school completed by population 25 years old and over in 1970.	12.014	.75	12.014	.75	12.014	.75	12.014	.75
OME	6	Medium number of years of school completed by population 25 years old and over in 1970.	10.266	1.72	10.266	1.72	10.266	1.72	10.266	1.72
WFE	6	W = white race O = other race	12.019	.63	12.019	.63	12.019	.63	12.019	.63
OFE	6	M = male F = female E = education	10.781	1.56	10.781	1.56	10.781	1.56	10.781	1.56
UN	6	Unemployment rate by state.	5.209	1.48	5.104	1.49	7.009	1.682	5.774	1.78
<u>Other Variable</u>										
MON	See text	Number of months since lower MPA has been implemented.	.308	.21	5.9	1.18	16.44	2.66	7.57	13.59

Notes to Table 2

a. The sources are:

- 1 = Enhanced Mortality Files
- 2 = Area Resource File
- 3 = Liquor Handbook
- 4 = Facts and Figures on Government Finance
- 5 = Survey of Current Business
- 6 = Statistical Abstract of the United States

b. All means and standard deviations are two-year averages:

For two-year periods, N = 50.

For 1970-75, N = 150.

c. The means and standard deviations in parentheses are weighted. The weight used is

$$n/\bar{n} ,$$

where n is the race-specific population.

Measurement of Independent Variables

Most of the variables are self-explanatory. Those that need special explanation are the border state price and border state age difference variables which will be elaborated on in this section.

The price and availability variables for distilled spirits are obtained from the Liquor Handbook. Beer and wine price measures are found in the bi-annual publication of tax rates in Facts and Figures on Government Finance. The retail selling price of a four-fifth quart of the nine leading brands of liquor is available on a state basis. This price includes taxes.

In a previous study of the demand of liquor (Simon, 1966), the price of Seagram 7 Crown was used to compute the elasticity of demand. His rationale for this procedure is that Seagram 7 Crown is the leading brand of liquor in the United States, and its price is commonly used as a standard in the liquor industry. This methodology will be adopted instead of alternative price specifications. Some researchers (Barsby and Marshall, 1977) have computed the price variable on the basis of sales data reported by state. The justification for rejecting this procedure is that due to border crossing between states and other effects sales data may be a very unreliable estimate of liquor actually consumed in a given state in a given year. In addition, sales data

are not available for the specific population group analyzed in this study. The own price of liquor, beer and wine is deflated by a state and time-specific cost-of-living index to obtain the own relative price of these variables (LIQPR, BEPR, WINPR.)⁵

The interstate price index was developed for the year 1967 by Fuchs, Michael, and Scott (1979). Cross-sectional price indexes for the years 1970-1975 are developed by assuming that year-to-year percentage changes for each state are equal to year-to-year percentage changes in the Bureau of Labor Statistics' Consumer Price Index for the United States as a whole. This index was chosen because it provided a specific index for each state. The Bureau of Labor Statistics publishes a "family budget" for 44 metropolitan and non-metropolitan areas, but 21 states do not contain a metropolitan area for which the family budget is constructed (Fuchs, Michael, and Scott, 1979).

Additional availability characteristics involved in the analysis are the number of licenses per capita issued by each state for the dispensing of alcoholic beverages, the type of control implemented on package store sales (control vs. license state), and the minimum age at which the population can purchase alcohol.

Some of the above characteristics are an indication of the true price of alcohol. The states are divided into

two groups according to the laws imposed on alcoholic beverages. The first type, the control state, is characterized by government-owned liquor stores and the second type, license state, is characterized by privately-owned stores licensed by the state. Consumption figures are generally lower for control states. The variable for type of control (TYPCON) takes the form of a dichotomous variable that equals zero if the state is a control state and one if the state is a license state. For control states, $n = 17$ and for license states, $n = 33$. The type of state control has remained constant throughout the relevant time period.

The number of licenses (NLIS) is per 1,000 population. Licenses are issued for on-premise sale only, for off premise sale only, and for on and off premise sales. NLIS includes the total number of licenses from any of the above categories.

The independent variable generally considered and cited as an important determinant of teen-age motor vehicle mortality rates is the minimum legal purchasing age. Each state has direct control of the age at which alcohol can be purchased. Typically, the same minimum purchasing age is imposed on the consumption of liquor, wine, and beer. However, a few states have two minimum purchasing ages. One is for distilled spirits and a lower one is imposed on the consumption of beer and wine. In addition, the maximum alcohol content of beer and wine is specified for the lower age group.

Typically the alcohol content of beer is limited to 3.2 percent and for wine 14 percent. Since there is a high correlation between changes in the liquor and beer purchasing ages, the minimum age for liquor (AGE) is chosen.

Throughout the period analyzed in this paper, changes have occurred in the minimum legal purchasing age variables for a number of locations. For the dependent variable as well as most independent variables, the datum is for a given year running from January to December. However, most of the legal age changes have occurred during the year. To compensate for these changes, the age variable defined for the year is calculated as:

$$AGE = AGE_0 (i_0/12) + AGE_1 (i_1/12)$$

where

Age₀ = value of age variable at beginning of period

Age₁ = value of age variable at end of period

i = number of months for each age variable

The difference in both prices and minimum legal purchasing age between states is addressed in the following manner. Lewis and Coate (1980) in a study of cigarette consumption have pointed out that it is difficult to define the relevant price variable due to the purchase, by those individuals in a high price area, of cigarettes in a lower priced border area. This problem presents itself in two ways regarding alcohol consumption. Not only may the price variable be lower, but the minimum purchasing age may be lower

in a border state. This problem is dealt with via the following method.

The incentive to travel to a lower price and/or age border state is higher the greater the difference between own price and lower border state price as well as own age and lower border state age. Increased travel distance will affect the probability of mortality. To control for the border phenomenon (out-of-state purchases) the difference between own price and lower border state price and the difference between own state and border state minimum purchasing age are obtained. The difference variables are not available on an individual basis, but on a state-specific basis. The difference variable will only be relevant for the percentage of the population that lives within a certain distance of a border state. The estimate of the relevant population is obtained by aggregating the population of countries that border a lower age and/or price state. The percentage of the border county population total to the state total is then multiplied by the difference variables to obtain weighted price and age differences. The weighted price difference and weighted age difference are entered as separate independent variables in the production functions. An increase in the difference variables should provide an incentive to travel to a border state.

The variable for the difference between own price and lower border state price is divided by the state-specific

cost-of-living index to obtain the relative price difference (APDR). The difference between the own state age and border state age is denominated in years (AMD).

Highway statistics included in the regressions are the legal state driving age, the amount of gasoline consumption per capita, estimates of the urban-rural driving mix, highway travel density, and a dichotomous inspection variable. The variable for driving age (DL) is the minimum age at which an individual can obtain permission to operate a standard passenger vehicle. In some states, the minimum age is reduced for those persons who have completed a driver education course. In most cases, the age was two years below the basic required age. The driving age used was then calculated as the average of the two. This was done to compensate for the larger driving population that exists in those states with a reduced age requirement for driver education completion. The amount of motor fuel consumption is included to allow for interstate differences in motor vehicle use. In the cross-section as well as over time, the variable is expected to be positively related to mortality rates because greater usage should result in higher death rates, *ceteris paribus*. The variable is measured in hundreds of gallons per capita. The rationale for including the inspection variable is that required motor vehicle inspection in a particular state may result in safer vehicles being operated by the driving public in that state. This is expected to reduce the mortality rate.

The effect of density and the urban-rural driving mix is somewhat complex. Sam Peltzman (1975) considers some of the effects of this variable in his study of automobile safety regulation. The variables entered in this analysis will follow a similar manner. To account for urban-rural death rate differences, the ratio of urban to rural highway mileage is entered as an independent variable (URR). States which are characterized by a large percentage of rural highways should have increased distance to be traveled to places at which alcohol is available. In addition to the urban-rural mix, rural and urban densities (MUNHT, RURHT) are employed. These densities are the amount of vehicle miles per respective highway miles.

The estimate for vehicle miles is computed as follows:

Estimates of vehicle mile data are based on traffic counts, fuel consumption, vehicle registrations, drivers licenses, and home interview data. Traffic volume information is obtained from automatic traffic recorders operating continuously at selected locations on the road and streets of each state. These recorders (more than 3,000 in 1975) are generally supplemented by seasonal manual clarification counts to determine volumes of vehicles of each type, and each highway category, and by portable machine counts on the many road and street sections.
(Highway Statistics, 1975)

Increased density is generally expected to increase the probability of an accident at a given speed and thereby the risk of death. Increased density, however, may force the average speed to be lower and can result in fewer deaths. Rural mortality rates are typically higher than urban rates

for the population as a whole. In the cross-section, the speed limit is not taken into account directly. Data on vehicle speed are not available on a state specific basis. The inclusion of the three variables (URR, MUNHT, RURHT) should provide an indirect estimate of the effects of speed.

The social and economic characteristics of youths in each state are represented by four variables. The first, the state per capita personal income as reported by the Survey of Current Business, is an indication of the adolescent's command over resources. Money income is deflated by the state Consumer Price Index to obtain real income (INCR). The number of hospitals with emergency rooms per capita (HOSP) serves as a proxy for the availability of medical resources to an accident victim. A sex and race specific education variable is entered to account for possible differences in the ability to read road signs, pay attention to safety and other factors. The education measures (WME, OME, WFE, OFE) are defined as the median number of school years completed by the population 25 years and older in 1970. Although the education variables are specified for a population group older than the relevant population in the analysis, the educational levels for the specific age groups, 15-24, were not available on a race and sex specific basis as was the education level for the older population. A comparison of the two age group educational levels specified for sex

only revealed that there was little or no difference between the two groups. Thus the older population educational level was used to control for race differences. The variable may also serve as a proxy for family background. The final variable is the state unemployment rate (UN). Though a higher unemployment rate may reduce the command over resources to purchase alcohol, gasoline, etcetera, it will also provide more leisure time available for alcohol consumption and driving. Unemployment could have psychological effects that may lead to increased alcohol consumption.

Footnotes

1. A Chow test was conducted to determine the equality of the test regression coefficients for the two race groups. The computed F-test rejected the hypothesis of the equality of the two sets of regression coefficients.
2. Since most of the independent variables are not race-specific the percentage of non-whites may be highly correlated with independent variables such as income.
3. Since the unit of observation is the state, the error terms associated with those states with larger populations may have larger variances than less populated states.
4. For three of the six time periods the number of motor vehicle mortality rates for the entire state summed to zero. It was felt that this was a result of a problem in the data tape since a value of zero was never recorded for any other state during any time period. The mortality rate for Wyoming for the years available was consistent with the mean of the population as a whole and the omission of this state would not alter the analysis.
5. Beer and wine tax rates later dropped from the analysis due to a high correlation with the liquor price variable. In preliminary work the coefficients of these variables were not significant.

CHAPTER IV

EMPIRICAL RESULTS

Section A of this chapter presents the ordinary least-squares regression estimates in the cross-section for the three time periods. The pooled time-series cross-section results are discussed in Section B. Section C tests the possibility of endogeneity of the law change in the model and Section D explores additional analyses. In preliminary work which tested for heteroscedasticity in the unweighted regressions (both in the cross-section and pooled analysis) no significant heteroscedasticity was found.¹ Therefore, only the unweighted results are discussed.

A. Cross Section

The ordinary least-squares regressions of white male and female and non-white male and female motor vehicle mortality rates for the three time periods are presented in Tables 3, 4, 5, and 6, respectively. These regressions contain the full set of independent variables listed in Table 2.

The results pertaining to the minimum legal purchasing age variable (AGE) vary with the differing groups. As mentioned in previous sections, this variable is generally cited as the principal cause of increased mortality rates for this age group and has been changed as a direct result of

state legislation. The findings of this study provide strong evidence that a lower MPA will result in higher mortality rates with respect to the white male and female group. For white males the age variable has the expected negative sign for all time periods, but does not reach a significant level until the third period. In this period AGE becomes significant at the one percent level. The age variable is also negative and significant at the five percent level in the third period for white females. In the case of non-white males and females, however, the coefficient of AGE is not significant for any of the three time periods. One important implication of the significant signs of the AGE variable for white males and females in the third-period is that a lag exists between the implementation of the law reducing the MPA and the consequences thereof. Thus, studies undertaken to examine changes in both consumption and mortality immediately succeeding an age change may not accurately state the full impact of law changes.

Before estimating the full impact of a change in the minimum legal purchasing age, the specification of the border phenomenon (the traveling to border states to purchase and/or consume alcohol because of differences in price and legal drinking ages) will be explored. The two variables,

TABLE 3

Regression Coefficients -- Mortality Rates White Males

Unweighted Ordinary Least Squares -- All Variables Linear

Independent Regression Variable	1970-71 Period 1 (n=50)		1972-73 Period 2 (n=50)		1974-75 Period 3 (n=50)	
	Coefficient	t-Ratio	Coefficient	t-Ratio	Coefficient	t-Ratio
LIQPR	.056	1.06	.125	2.93	.046	1.36
APDR	-1.55	-1.40	-.077	-.089	.665	1.50
AGE	-.036	-1.01	-.011	-.725	-.024	-2.89
AMD	.092	1.85	.027	.718	.042	1.68
NLIS	.077	2.16	.069	2.33	.026	1.47
TYPCON	-.133	-2.68	-.088	-2.38	-.064	-2.58
MUNHT	-.907-04	-2.88	-.357-04	-1.96	-.210-04	-1.99
URR	-.067	-1.99	-.033	-1.53	-.049	-2.76
GCPC	.190-02	4.57	.143-02	5.13	.137-02	6.69
DL	-.060	-1.65	.026	1.027	.027	1.56
INSP	-.003	-.063	-.052	-1.53	-.018	-.802
INCR	.174-04	.200	-.692-04	-1.32	.105-04	.277
HOSP	.385	1.09	.128	.472	-.007	-.031
UN	.004	.024	-.023	-1.84	.004	.057
WME	-.104	-2.88	-.092	-3.55	-.051	-2.68
Constant	2.8159		.9421		.5120	
Adj. R ²	.733		.791		.792	
F*	9.96		13.396		13.467	

*F-ratios are significant at 1 percent level. The critical t-ratio is 1.679 at 5 percent level for a one-tailed test.

TABLE 4

Regression Coefficients -- Mortality Rate White Females

Unweighted Ordinary Least Squares -- All Variables Linear

Independent Regression Variable	1970-71 Period 1 (n=50)		1972-73 Period 2 (n=50)		1974-75 Period 3 (n=50)	
	Coefficient	t-Ratio	Coefficient	t-Ratio	Coefficient	t-Ratio
LIQPR	.022	1.11	.049	2.06	.046	2.10
APDR	.454	1.10	-.338	-.707	-.017	-.063
AGE	.002	.145	.004	.505	-.011	-1.98
AMD	-.014	-.778	-.004	-.167	.010	.622
LIS	.026	1.87	.038	2.15	.018	1.50
CON	.008	.407	.002	.070	-.018	-1.07
MUNHT	-.941-05	-.784	-.526-05	-.506	-.489-05	-.718
URR	-.019	-1.59	-.017	-1.47	-.014	-1.27
GCPC	.642-03	4.30	.362-03	2.40	.311-03	2.46
DL	.218-03	.000	-.017	-1.22	-.006	-.570
INSP	-.030	-1.83	-.006	-.330	-.010	-.686
INCR	-.670-04	-2.25	-.233-04	-.789	-.205-04	-.878
HOSP	-.026	-.197	.044	.288	-.026	-.241
UN	.018	.319	-.149-03	-.000	-.007	-1.49
WFE	.716-03	.031	-.019	-.754	.005	.232
Constant	.0346		-.3615		.2802	
Adj. R ²	.608		.444		.440	
F*	6.058		3.607		3.568	

*F ratios are significant at 1 percent level. The critical t-ratio is 1.679 at 5 percent level for a one-tailed test.

TABLE 5

Regression Coefficients -- Mortality Rate Non-White Males

Unweighted Ordinary Least Squares -- All Variables Linear

Independent Regression Variable	1970-71		1972-73		1974-75	
	Period 1 (n=50) Coefficient	t-Ratio	Period 2 (n=50) Coefficient	t-Ratio	Period 3 (n=50) Coefficient	t-Ratio
LIQPR	.402	1.67	.834	2.53	.824	2.87
APDR	-4.73	-.950	-.181	-.003	3.52	.954
AGE	-.015	-.089	.045	.383	.032	.456
AMD	.062	.274	-.231	-.803	.035	.167
LIS	.293	1.76	.548	2.34	.505	3.25
CON	-.095	-.431	-.199	-.704	-.271	-1.27
MUNHT	-.122-04	-.083	.180-03	1.27	.857-04	.957
URR	.008	.055	.104	.645	-.045	-.305
GCPC	.004	2.32	.289-02	1.40	.016	.978
DL	-.115	-.719	-.958	-.295	.008	.055
INSP	-.108	-.523	-.076	-.292	-.058	-.302
INCR	-.613-03	-1.86	-.857-03	-2.28	-.645-03	-2.29
HOSP	1.358	.889	.844	.432	1.04	.710
UN	-0.85	-1.24	-.156	-1.48	-.015	-.228
OME	.125	2.08	.235	2.85	.185	3.09
Constant	0.421		-3.310		-3.994	
Adj. R ²	.343		.279		.440	
F*	2.706		2.266		3.570	

*F-ratios are significant at 5 percent level. The critical t-ratio is 1.679 at 5 percent level for a one-tailed test.

TABLE 6

Regression Coefficients -- Mortality Rate Non-White Females

Unweighted Ordinary Least Squares -- All Variables Linear

Independent Variable	1970-71		1972-73		1974-75	
	Period 1 (n=50)	t-Ratio	Period 2 (n=50)	t-Ratio	Period 3 (n=50)	t-Ratio
LIQPR	.213	1.77	.338	2.23	.331	2.97
APRDR	-3.30	-1.35	-6.89	-2.28	-1.74	-1.19
AGE	.052	.649	.037	.704	.016	.587
AMD	.634	.566	.251	1.92	.032	.399
LIS	.167	2.04	.211	1.98	.098	1.64
CON	.068	.618	-.058	-.499	-.027	-.320
MUNHT	-.822-04	-1.17	-.107-03	-1.66	-.102-05	-.032
URR	-.012	-.167	-.047	-.635	.045	.778
GCPC	.957-03	1.07	.852-03	.904	.440-03	.683
DL	-.022	-.279	-.124	-1.38	-.085	-1.52
INSP	-.038	-.370	.012	.100	.073	.967
INCR	-.414-03	-2.55	-.576-04	-.336	-.157-03	-1.44
HOSP	-.202	-.268	1.32	1.47	.240	.420
UN	-.035	-1.04	-.012	-.247	-.027	-1.09
OFE	.103	2.73	.157	3.25	.123	4.06
Constant	-1.383		-1.609		-0.795	
Adj. R ²	.363		.373		.353	
F*	2.864		2.947		2.779	

*F-ratios are significant at 5-percent level. The critical t-ratio is 1.679 at 5 percent level for a one-tailed test.

APDR and AMD, measuring the difference between the own state price and a lower border state price and the difference between the own state minimum purchasing age and the border state minimum purchasing age, respectively, were entered as independent variables. Tables 7 and 8 present estimates of the effect of price, age, and price and age differences for the three time periods. Each regression includes all highway, availability, social and economic variables. Regression (1) of each time period includes the price (APDR) and age (AMD) differences while regression (2) omits it. Separate regressions using a subsample of states in which the age difference is zero (the border age is either equal to or larger than the own age) were estimated for both groups. Due to the small sample size ($n < 25$) for some of the subgroups, many of the regressions were not statistically significant and the results are, therefore, not presented. It should be noted, however, that for the regressions which were significant, there was little or no variation in the coefficients for the separate group.

In the regressions that include the difference variables (APDR and AMD), as well as those regressions excluding these variables, the liquor price variable (LIQPR) is again positive and significant nine out of twelve times. The price difference variable (APDR) is only significant for non-white females in Period 1, but has the "wrong" sign.

TABLE 7
 Regression Coefficients of Price, Age, and Difference Variables
 Alternative Specifications ^(a)

White Males						
Independent Variable	1970-71		1972-73		1974-75	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
	With AMD	Without AMD	With AMD	Without AMD	With AMD	Without AMD
LIQPR	.056 (1.06)	.035 (.655)	.125 (2.93)	.123 (2.97)	.046 (1.36)	.063 (1.75)
AMD	.095 (1.85)		.027 (.718)		.042 (1.68)	
APDR	-1.55 (-1.40)		-.077 (-.089)		.665 (1.50)	
Age	-.036 (-1.01)	-.020 (-.555)	-.011 (.725)	-.007 (-.521)	-.024 (-2.89)	-.016 (-1.93)
Adj. R ²	.733	.719	.791	.800	.792	.760

White Females						
LIQPR	.022 (1.11)	.026 (1.37)	.049 (2.06)	.047 (2.05)	.046 (2.10)	.047 (2.25)
AMD	-.014 (-.778)		-.004 (-.167)		.010 (.622)	
APDR	.454 (1.10)		-.338 (-.707)		-.017 (-.063)	
Age	.002 (.145)	.001 (.077)	.004 (.505)	.003 (.396)	-.011 (-1.98)	-.009 (-1.93)
Adj. R ²	.608	.615	.444	.465	.440	.465

^at-ratios are in parentheses. The critical t-ratio at the 5 percent level is 1.679 for a one-tailed test. The F-ratios are all significant at the 1-percent level.

TABLE 8

Regression Coefficients of Price, Age and Difference Variables
Alternative Specifications^a

Non-White Males						
Independent Variable	1970-71		1972-73		1974-75	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
	With AMD	Without AMD	With AMD	Without AMD	With AMD	Without AMD
LIQPR	.402 (1.67)	.370 (1.59)	.834 (2.53)	.845 (2.65)	.824 (2.87)	.877 (3.14)
AMD	.062 (.274)		-.231 (-.803)		.035 (.167)	
APDR	-4.73 (-.950)		-.181 (-.003)		3.52 (.954)	
AGE	.015 (.089)	.003 (.000)	.045 (.383)	.014 (.130)	.032 (.456)	.049 (.759)
Adj. R ²	.343	.363	.279	.305	.440	.454

Non-White Females						
LIQPR	.213 (1.77)	.187 (1.60)	.338 (2.23)	.271 (1.70)	.331 (2.97)	.313 (2.88)
AMD	.634 (.566)		.251 (1.92)		.032 (.399)	
APDR	-3.30 (-1.35)		-6.89 (-2.28)		-1.74 (-1.19)	
AGE	.052 (.649)	.068 (.866)	.037 (.704)	.057 (1.05)	.016 (.587)	.015 (.606)
Adj. R ²	.363	.366	.373	.286	.353	.363

^at-ratios are in parentheses. The critical t-ratio at the 5-percent level is 1.679 for a one-tailed test. The F-ratios are all significant at the 1-percent level.

For white males, the coefficient of the age difference (AMD) is positive and significant for two of the three time periods. This variable (AMD), however, is not significant when applied to non-white males, white females, and is only significant in Period 1 for non-white females.

As the results show, the border problem (crossing state lines to obtain alcohol) is clearly relevant with regard to the age effects for white males. The significance of the value of the border age difference (AMD), for males in the white race group indicates those states which have on their border states with a lower drinking age can expect to have a higher motor vehicle mortality rate. If the incentive to search for sources of alcohol requires increased travel distance and results in driving back to the higher age state while under the influence of alcohol the cost of this search (in terms of lives) is clearly evident.

The total impact of a change in the minimum legal purchasing age can now be evaluated. A reduction in the MPA in one state will not only increase mortality in the state instituting the law change but this change may also increase mortality in the border state. The findings of this paper suggest that for the white age group, a reduction in the minimum legal purchasing age will result in an increase in the mortality rate by .0612. Thus it can be approximated that 70 more deaths for this age group can be expected in

a state like Michigan. This would imply a 10 percent increase in the motor vehicle mortality rate for those states lowering the minimum purchasing age.²

The results regarding the remaining independent variables are now discussed.

The most striking find is that the liquor price variable (LIQPR) is positive and significant nine out of twelve times. This may be the result of the "wrong" sign for the elasticity of demand. To test for this, a separate regression was run similar to that of Barsby and Marshall (1977) using data on the apparent consumption of alcohol (APC). The dependent variable (APC) is defined as the annual per capita (entire state population) consumption of alcohol (APC). The dependent variable (APC) is defined as the annual per capita (entire state population) consumption of distilled spirits based on the volume of sales to both wholesalers and retailers. This variable was regressed on both the liquor price variable (LIQPR) and a number of additional explanatory variables. The results indicated that in each time period, the liquor price variable both was negative in sign and significant with the value of the price elasticity ranging from $-.826$ to -1.09 .³ These values were consistent with those found in previous studies (Simon; 1966, Barsby and Marshall; 1977). The main impact of this finding is to reject the conclusions of researchers who have attempted to estimate the effect of changes in variables on apparent consumption for the entire population and then used

this result to explain changes in mortality rates for a certain population group. (See for example Barsby and Marshall; 1977). The price effect for this age group may not be the same as that for the population at large.⁴

The coefficient of the availability measure, NLIS is positive and significant for nine out of the twelve regressions. A larger number of licenses per capita implies increased access and lowers the cost of obtainment. While increased access may also require less travel and a possible lower probability of mortality, the positive sign of the coefficient of NLIS provides support to the contention that increased availability of alcohol adds to increases in consumption and mortality.

With regard to the availability measure TYPCON, a dichotomous variable that equals one if the state is a license state (privately-owned liquor stores) and zero if the state is a control state (state monopoly of liquor stores), the coefficient is not significant for all but white males in the three time periods. For white males in each time period, however, the coefficient had the "wrong" sign. To further analyse the difference between control and license states t-tests were performed on the means of a number of variables. As Table 9 indicates for all time periods, the mean of mortality rates is higher for control states for this group (white male). Though there are no

TABLE 9

Selected Means for Control vs. License States

Variable	Period 1 1970-71		Period 2 1972-73		Period 3 1974-75	
	Control*	License**	Control	License	Control	License
	Means		Means		Means	
MRWM	0.8944 t = 1.72	0.7703	.8682 t = 1.73	0.7594	0.7229 t = 1.52	0.6576
MROM	0.9597 t = 0.64	0.7703	1.0029 t = 0.78	.7944	0.7524 t = 1.01	0.5253
MRWF	.2482 t = .28	.2420	.2439 t = .02	.2435	.2088 t = .84	.1944
MROF	.3009 t = .47	.2503	.3245 t = -.50	.3900	.2038 t = -.29	.2276
LIQPR	4.3631 t = -0.20	4.3937	4.1582 t = 0.09	4.1445	3.5696 t = -0.03	3.5737
AGE	20.8676 t = 0.87	20.6970	20.00 t = 0.76	20.0424	19.6176 t = 0.03	19.6061
NLIS	0.8432 t = -2.28	1.3098	0.8959 t = -2.09	1.3211	0.9765 t = -1.86	1.3930

*For Control States N = 17.

**For License States N = 33.

significant differences between the price and age variables, the large t-value for the variable NLIS stands out. Those states that exercise stricter control over the dispensing of alcohol do so in one respect by limiting the number of licenses per capita.

A plausible explanation for the "wrong" sign of the control variable (TYPCON) for white males is the degree of correlation between this variable and the number of licenses (NLIS). When TYPCON was dropped from the analysis the license variable (NLIS) was no longer significant in the second or third periods for white males. For other groups the significance of NLIS was not altered. The important message conveyed in the data is that efforts to control the negative aspects of alcohol consumption by prohibiting access may not necessarily achieve the desired results.

Turning now to the highway variables, the effect of gasoline consumption per capita (GCPA) on motor vehicle mortality is clearly evident. A look back at the means of the mortality rates and gasoline consumption per capita shows the decline in both over time. This is attributed to both the higher gasoline prices which occurred in the 1970's and the reduction in the speed limit to a maximum of 55 miles per hour at the end of 1974 (See National Safety Council Reports, 1974-1975).

The sign of GCPA is positive and significant in all time periods for the white population group. Though

only significant for the non-white population on the male side in the first time period the important result is that for both groups the positive effect of a decline in gasoline consumption has been lower mortality rates.

The interpretation of the highway variables reflecting both driving density (MUNHT, RURHT) and the urban-rural highway mix (URR) is complex. For non-white males and females as well as for white females none of the variables are statistically significant. In working with alternative specifications to control for the effect of density, the same result was also obtained. The variable RURHT was dropped from the analysis due to a high correlation with MUNHT. Variations in mortality rates for all but white males cannot be explained by the two above variables (MUNHT, URR). For white males these highway variables (MUNHT, URR) are significant five out of six times. These results show that while increased density may increase the probability of an accident, and thereby death, the discouragement of faster driving due to this density appears to dominate. The sign of URR suggests that the reduction in mortality rates over time as a result of lower gasoline consumption and lower speed limits is much less effective in rural areas. This helps to explain the persistent excess of rural over urban death rates.

The inspection variable (INSP) is always negative in sign but is only significant in one of the regressions.

This outcome does not conflict with the findings of Fuchs and Leveson (1967) that vehicle inspection is effective in reducing mortality.

The minimum age for obtaining a drivers license (DL) is the last variable to be considered relating to highway effects. For all but the second and third time periods the expected negative sign is confirmed, but the significance is rejected at the 5 percent level. The DL variable has the "wrong sign" for white males in two time periods. The coefficient, however, is not significant.

The social and economic variables (INCR, HOSP, WME, WFE, OME, OFE, UN) are now briefly discussed. The effect of income is much more prominent for the non-white group. The higher mortality rates for this group appear to be concentrated in those states where income is lowest. For the white group, differences in income does not contribute to differences in mortality rates among states. The variable used as a proxy for the availability of health care (HOSP) varies in sign but is never significant. The unemployment variable (UN) is only significant in the immediate time period for white males.

The education measures have a significant effect for all time periods for all but the non-white female group. The surprising result is that the effect is exactly opposite for the two race groups. For non-white males, the coefficient

is negative. The negative sign of WME is as was expected. Higher educational levels may imply increased awareness of the dangers associated with drinking and driving, but the positive sign of the education variable for non-whites cannot be explained.

B. Pooled Time-Series Cross-Section

This section presents estimates of the effects of the various independent variables on race and sex-specific mortality rates for the period 1970-1975. The two year averages of both the dependent and independent variables in the cross-section are pooled for the three time periods (1970-71, 1972-73, 1974-75) using unweighted ordinary least-squares.

The difficulty that sometimes arises when using pooled data is that the error term may be correlated both over time and over cross-section units. If this occurs pooling is inappropriate and generalized least-squares estimation is necessary. The techniques of covariance analysis can be used to test:³

- (a) differences in intercepts (slopes assumed constant for all time periods).
- (b) differences in slopes between time periods, which will indicate if pooling is appropriate.
- (c) if residuals for given areas are correlated over time.

To test (a) a comparison is made between the pooled ordinary least squares-model and the following pooled ordinary least-squares model with dummy variables:

$$(14) \quad D_{it} = a_0 + b_0 X_{it} + c_0 W_{i2} + C_1 W_{i3}$$

where

$$W_{i2} = \begin{cases} 1 & \text{for time period 2} \\ 0, & \text{otherwise} \end{cases} \quad i = 1 \dots 50$$

where

$$W_{i3} = \begin{cases} 1, & \text{for time period 3} \\ 0, & \text{otherwise} \end{cases} \quad t = \text{time} = 1, 2, 3$$

where X_{it} = vector of $(k - 1)$ independent variables. The test of the hypothesis of constant intercepts over time is given by the F statistic

$$F_{(a)} = \frac{(RSS_2 - RSS_1) / (t - 1)}{RSS_2 / (it - t - k + 1)}$$

with $(t - 1, it - t - k + 1)$ degrees of freedom where

RSS_1 = residual sum squares using ordinary least squares without dummy variables.

RSS_2 = residual sum squares using ordinary least squares with dummy variables.

The results of the F-tests revealed that the intercept effect is significant.

The above test is conditional on the assumption of a common set of slope coefficients over all the time periods, so this assumption requires testing. The test of a constant set of slope coefficients is given by:

$$F_{(b)} = \frac{RSS_2 - RSS_3 / (tk - t - k + 1)}{RSS_3 / t(i - k)}$$

with $(tk - t - k + 1, t(i - k))$ degrees of freedom where

RSS_3 = summation of residual sum squares for each separate time period using ordinary least-squares.

The results of the F-tests revealed that the assumption of constant slope coefficients is accepted.

To test the possibility of the correlation of the error terms for given areas over time pooled regressions that included region-specific dummy variables ($n = 8$) were tested.⁶ In each case both the region variables and the appropriate F-statistic were not significant. Thus, the ordinary least-squares model that included time-specific dummy variables to compensate for changes in intercepts was chosen as the best specification for the pooled analysis.

The independent variables in the pooled regressions are the same as that for the cross-section. In addition, two dummy variables (YEAR 72-73, YEAR 74-75) are entered for the 1972-73 and 1974-75 time periods, respectively. Tables 10 and 11 present the results for the four groups. The signs of most of the coefficients are similar to those discussed in the cross-section. Many of the variables, however, have now become significant at the 5 percent level.

TABLE 10

Regression Coefficients -- Pooled Data 1970-1975

White Males and Females -- All Variables Linear				
Independent Variable	White Males (n = 150)		White Females (n = 150)	
	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.081	2.98	.035	3.01
APDR	-.312	-.679	-.057	-.292
AGE	-.022	-2.31	-.004	-.975
AMD	.046	2.00	-.001	-.145
NLIS	.042	2.46	.025	3.41
TYPCON	-.064	-2.83	-.001	-.148
MUNHT	-.367-04	-3.28	-.839-05	-1.75
URR	-.048	-3.41	-.020	-3.31
GCPC	.002	10.14	.442-03	6.61
DL	.009	.537	-.010	-1.39
INSP	-.018	-.828	-.014	-1.56
INCR	-.737-04	-2.24	-.336-04	-2.52
HOSP	.138	1.19	-.016	-.331
UN	.002	.261	-.444-03	-.148
Year 72-73	-.051	-1.85	.680-03	.055
Year 74-75	-.112	-2.78	.021	1.25
WME-WFE	-.050	-4.05	-.008	-1.133
Constant	.8959		.3459	
Adj. R ²	.742		.587	
F*	26.31		13.44	

*F-ratios are significant at 1 percent level. The critical t-ratio is 1.64 at the 5 percent level for a one tailed test.

TABLE 11

Regression Coefficients -- Pooled Data 1970-1975

Non white Males and Females -- All Variables Linear				
Independent Variable	Non-White Males (n = 150)		Non-White Females (n = 150)	
	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.615	4.06	.260	3.47
APDR	.745	.291	-3.26	-2.58
AGE	.024	.478	.023	.913
AMD	-.044	-.352	.105	1.68
NLIS	.413	4.24	.159	3.35
TYPCON	-.158	-1.24	.444-03	.000
MUNHT	.765-04	1.22	-.607-04	-1.96
URR	-.012	-.155	-.028	-.761
GCPC	.003	3.35	.791-03	1.74
DL	-.035	-.395	-.074	-1.66
INSP	-.030	-.253	.031	.534
INCR	-.683-03	-4.01	-.171-03	-2.06
HOSP	.938	1.44	.338	1.05
UN	-.052	-1.36	-.005	-.260
Year 72-73	.219	1.42	.187	2.45
Year 74-75	.429	1.92	.230	2.09
OME-OFE	.157	4.53	.080	4.31
Constant	-2.7515		-.8264	
Adj. R ²	.428		.339	
F*	7.55		5.49	

*F-ratios significant at 1 percent level. The critical t-ratio is 1.64 at the 5 percent level for a one tailed test.

The highway variables results are as expected. The level of gasoline consumption clearly dominates. This suggests that any government policy that helps to reduce both the amount and speed of driving will prove beneficial. Once again the mortality problem is greater for those areas primarily rural. Increased density (MUNHT) may increase the probability of an accident but the reduced speeds in these areas limit the severity of such accidents. An excess of rural over urban death rates (URR) applies to the 15 to 24 year old age group as it does to the population as a whole. Differences in driver's license ages and inspection requirements do not help to explain differences in mortality rates for this specific age group.

The level of income (INCR) is negative and significant for all groups at the one percent level. The education variables are also significant for all groups, but the sign varies depending on the race group. For the non-white group, the sign of OME and OFE is positive. These results are consistent with those of the cross-section analysis. The t-values for the unemployment rate (UN) and for the level of medical care (HOSP) are not significant for any groups.

The alcohol availability measures each have the expected sign except for TYPCON for the white male group. The sign of the number of licenses per capita (NLIS) is positive and significant for all regressions. The positive

and highly significant sign of NLIS provides additional support for the contention that increased availability may lead to increased consumption. The dummy variable for the type of control (license vs. control state) is not significant except for white males. When TYPCON was dropped from the analysis the license variable (NLIS) was no longer significant. This implies again that for this group increased control over distribution of alcohol may not help to lower mortality.

The age variable (AGE) is significant at the one percent level for the white male group. For the remaining three groups, this variable is not significant. The coefficient of the age variable in the pooled analysis is similar in value (.022) to that obtained in the cross-section for the 1974-75 time period (.024). An estimation of the impact of a reduction in the minimum purchasing age from 21 to 18 reveals that for the white male group approximately 70 more deaths per 1,000,000 population can be expected as a result of such changes. This estimate implies a 10 percent increase in motor vehicle mortality rates for this group and is consistent with earlier findings.

The appropriateness of the specification of the border age problem is again supported and is clearly a relevant issue. The coefficient of the difference between the own state minimum purchasing age and the border state

MPA (AMD) is positive and significant at the one percent level for white males and is significant at the 5 percent level for non-white females. This result suggests (as did previously) that state-specific estimates of increases in mortality rates among the teenage population may understate the full impact of such changes. An examination of changes in mortality rates for those localities bordering the change state is necessary to fully evaluate the effect of government regulations in this area. The findings of this study address those issues brought forth by Wagenaar (1981) as to the need to examine in greater detail the cross-border problem before making a blanket recommendation as to changes in regulations regarding the minimum legal purchasing age of alcohol. The recommendation of a MPA uniform across states is generally supported.

C. Testing for Endogeneity

The previous empirical conclusions as to the effect of changes in the minimum legal purchasing age on teenage motor vehicle mortality rates were made under the assumption that the change in the government regulation (decrease in AGE) was exogenous. As noted by Edwards (1978) the assumption of the exogeneity of a law may be erroneous. As a result, the findings are subject to criticism and may yield misleading conclusions about the effectiveness of legislation. The

statistically significant coefficients of the age variable in the third time period for the white group may merely reflect that fact that (1) states that lowered the MPA had higher mortality rates in the previous time period or (2) states which did not implement reductions in the MPA had lower mortality rates in the previous time period and did not implement the law change for fear of increasing the mortality rates. If the age variable (AGE) is equally effective in the 1970-71 time period as it is in the 1974-75 time period there is an indication that this variable is reflecting something other than a change in regulation effect.

To test for possible endogeneity, the age variable (AGE) in equation 13 (Chapter II) for time period 1970-71 is replaced by a new age variable AGE 75. This variable (AGE 75) represents the minimum legal purchasing age for each state in time period 1974-75. If the estimates of the coefficients of the age variable for 1974-75 are of similar value and statistically significant in the 1970-71 time period it is a clear indication that the variations in mortality rates in the succeeding time period have not come about from changes in the law.

The results of the estimates of the coefficients appear in Table 12. The coefficient estimates for AGE 75 are both lower in value and not statistically significant

TABLE 12
 Regression Coefficients of Alternative AGE Variables
 in the 1974-1975 Period

Race-Sex	Group	Regression Coefficient		t-ratio	
		AGE	AGE 75	AGE	AGE 75
White	Males	.024	-.009	-2.89	-.507
White	Females	-.011	.003	-1.98	.580

The critical t-ratio is 1.679 at the 5 percent level for a one-tailed test.

for those groups in which the original age variable (AGE) was significant. The increase in mortality rates for those states which lowered the minimum legal purchasing age is clearly a result of such legislation. Therefore, the results in sections A and B can be interpreted as unbiased estimates of the effects of the minimum legal purchasing age variable.

D. Additional Analyses

The availability of the data in the cross-section as well as over time enables additional analyses to be performed to further examine the effects of changes in the legal minimum purchasing age. The first analysis allows for a lagged effect of the legal drinking age. To be specific the following models are estimated:

$$(15) \quad D_{it} = a_0 + a_1 A_{it} + a_2 L + u$$

$$(16) \quad D_{it} = a_0 + a_1 A_{it} + a_2 L + a_3 L^2 + u$$

where L = number of months since drinking age was lowered.

The first model (equation 15) allows for the possibility of a lagged effect of changes in the MPA. The second model (equation 16) allows for the possibility of a lagged effect but also captures the fact that in a given state the effect may fall over time. The results are presented in Table 13.

In the regression equation of both models the correlation coefficient between the minimum legal purchasing

TABLE 13
Regression Coefficients -- MON*

Race-Sex	Group	Number of months since law change			
		1972-73	1974-75	1970-75	1970-75
		1	2	3	4 (MON ²)
White	Males	.002 (1.16)	.002 (4.29)	.005 (1.83)	.062-04 (.975)
White	Females	.326-03 (.279)	.001 (3.30)	.977-04 (.089)	.225-04 (.818)
Non White	Males	-.005 (-.321)	.586-05 (.000)	-.023 (1.59)	.661-03 (1.69)
Non White	Females	-.002 (-.308)	-.749-03 (.359)	.003 (.392)	-.881-04 (.449)

*t-ratios are in parentheses.

The critical t-ratio is 1.679 at the 5 percent level for a one-tailed test.

age (AGE) and the number of months since the MPA was reduced (MON) was very high ($r = -.78$). It is known that these two variables move together since a decrease in the age variable (AGE) results in an increase in the month variable (MON). The model was re-estimated with the variable for age (AGE) dropped. The coefficient of the variable MON for the 1972-1973 time period (Period 2) is shown in Column 1 of the table. Columns 2 and 3 show the results for the 1974-1975 (Period 3) and 1970-1975 (pooled data) time periods respectively. The results of the coefficient of the square of MON to control for the possibility of a decrease in the lagged effect over time is shown in Column 4.

The results are significant for the white race group only, and is consistent with the earlier findings on the effects of changes in AGE for this group. Despite the high correlation between AGE and MON, the results indicate that the effect of a change in the MPA does not fall over time but rather the effect is more prominent in the period succeeding the change for at least one year. Thus studies that have examined the changes in mortality rates immediately following the reduction in the MPA may not fully estimate the impact of such change.

In the second analysis, the change in the dependent variable (mortality rate for each group) was regressed on

the change in the independent variables for the period 1970-75. Since some of the independent variables did not vary over time, these variables were dropped from the analysis. The F-statistic on the entire equation for all race and sex groups was not significant and the results are not presented.

Footnotes

1. The Goldfeld-Quandt (1965) test was applied to the cross-section regressions by ordering the regressions by race-sex specific population. In all cases the F-statistic calculated on the residuals was not significant. Thus homoscedasticity of the error terms was assumed.
2. This result was obtained from the following model.

$$D = a_b + a_1 A_0 + a_2 k (A_D - A_b) \text{ where}$$

A_1 = border state MDA

A_D = own state MDA

k = percent age of population living in counties that border a given state.

$$\frac{\partial D}{\partial A_0} / \bar{A}_1 = a_1 + k a_2 \quad a_1 = -.024, a_2 = .042, k = .079$$

3. These results are taken from a forthcoming study of the demand for alcohol by the author.
4. The positive sign of the liquor price variable may be due to substitution effects. Although the variable for beer price was not significant in any of the regressions both beer and illegal drugs are substitutes for distilled spirits. A higher price for liquor can result in a substitution towards beer and illegal drugs. The consumption of beer and drugs impedes the ability to drive and thus may increase the probability of mortality. The unavailability of price data for illegal drugs, however, does not enable this conclusion to be confirmed.
5. This method of testing is adopted from J. Johnston (1972).
6. The F-test used is for the pooled analysis is:

$$F(c) = \frac{(RSS_1 - RSS_4) / (i - 1)}{(RSS_4) / (it - i - 1)}$$

with $(i - 1, it - i - 1)$ degrees of freedom where

RSS_4 = residual sum of squares using cross-section dummy variables.

States were grouped into nine specific regions and the dummy variable was specified for each specific region. This was necessary because of computer limitations as to the number of independent variables. In addition, for each time period regressions that included the region dummy variables did not differ from those that were run without the dummy variables. The coefficients of the dummy variables were not significant in any of the regressions. Thus, it is assumed that errors for areas are not correlated over time.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study has been to examine the effects of government regulations on motor vehicle mortality rates for the fifteen to twenty-four year old age group for white and non-white males and females. Particular emphasis is placed on the role of changes in the minimum legal purchasing age of alcohol in the jurisdictions under consideration. The main conclusions of this study are (1) a lower minimum legal purchasing age increases the probability of mortality for both the white male and female group in the time period that succeeds the change in the law by at least one year, but does not have any effect on mortality for non-whites; (2) those states which have on their borders states with a lower MPA can expect to have a higher probability of mortality as a result of border crossing; (3) the level of gasoline consumption per capita explains a significant portion of the variation in mortality rates both in the cross-section as well as over time; (4) alcohol price variables (including tax) are positively related to mortality rates; and (5) a greater number of licences per capita, implying increased availability of alcohol, plays

an important role in determining motor vehicle mortality rates; (6) only for white males does increased state control of dispensing of alcohol have an impact on mortality rates.

With respect to the first conclusion, the reduction in the minimum legal purchasing age from 21 to 18 is expected to increase by 10 percent the number of deaths for the 15-24 year old population. This result is obtained both in cross-sectional and pooled analysis and is consistent with additional studies that confirm the negative impact of reduced MPA's.

The significance of the border problem adds additional support to the contentions of a negative impact of a reduction in the MPA. The search for sources of alcohol availability may prove costly (in terms of lives) if this search necessitates driving to those areas (neighboring states) in which alcohol is available. Returning to the home state while under the influence of intoxicating beverages may increase the probability of an accident and perhaps death. This result addresses the issue put forth by Wagenaar (1981) as to the need to investigate the border problem and suggests that studies which have concentrated on variations in mortality rates in a single state only after reductions in the MPA may understate the true cost of such legislation.

The role of gasoline consumption per capita and its influence on mortality rates suggests that programs

designed to reduce the speed and level of driving would result in decreases in mortality rates not only for the age group under question but possibly for the population as a whole. In addition, the higher probability of mortality in rural areas may signal the need for greater law enforcement in these areas. Increased prevention of both speeding and driving under the influence of alcohol could be an effective policy tool.

The two availability factors, the number of licenses per capita and the price of alcohol, underline the need for an evaluation of present governmental regulations designed to control the use and/or abuse of alcohol. A higher number of establishments able to offer alcohol for sale may provide economic benefits in terms of convenience or revenue, but these benefits must be weighed against the possible increase in cost, namely a higher teenage motor vehicle mortality rate. The positive coefficient of the liquor price variable suggests that price effects for the population as a whole can vary among sub-groups.

Overall, the results of this study are quite conclusive with respect to the white population group as to the effects of a reduction in the minimum legal purchasing age on teenage motor vehicle mortality rates while allowing for variations in additional factors that contribute to mortality. The results indicate that efforts

to raise the MPA not only would reduce mortality rates in the states implementing this increase, but also reduce mortality rates in the border states with an existing higher MPA. The suggestion that the minimum legal purchasing age be mandated at the national level and is consistent in each jurisdiction could be a quite effective policy tool to reduce the overall number of motor vehicle mortalities nationwide for the fifteen to twenty-four year old age group. The estimated effect of a uniform minimum legal purchasing age of twenty-one nationwide would be a reduction of approximately 1,000 teenage motor vehicle mortalities. Thus, the payoffs to such legislation may be substantial.

APPENDIX

TABLE 14

Weighted Coefficients -- Mortality Rates -- White Males

Weighted Ordinary Least Squares -- All Variables Linear						
	1970-1971		1972-1973		1974-1975	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
Independent Variable	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.074	1.53	.104	2.52	.044	1.31
APDR	-1.69	-1.49	-.314	-.318	.568	1.13
AGE	-.042	-1.31	-.012	-.839	-.022	-2.67
AMD	.059	1.30	.025	.636	.042	1.74
NLIS	.072	2.01	.064	2.08	.023	1.22
TYPCON	-.112	-2.38	-.073	-2.05	-.050	-2.13
MUNHT	-.661-04	-2.12	-.315-04	-1.50	-.191-04	-1.96
URR	-.046	-1.29	-.019	-.841	-.051	-2.61
GCPC	.002	3.86	.002	4.91	.001	6.43
DL	-.067	-1.78	.011	.374	.025	1.29
INSP	-.027	-.638	-.056	-1.63	-.022	-1.02
INCR	.211-04	.246	-.453-04	-.779	.825-06	0.00
HOSP	.436	1.19	.118	.379	.053	.259
UN	-.899-03	-.063	-.017	-1.22	.004	.645
WME	-.106	-2.74	-.105	-3.32	-.044	-2.13
Constant	3.039		1.275		.420	
Adj. R ²	.692		.725		.757	
F*	7.58		8.73		10.12	

*F-ratios significant at 1 percent level. The critical t-ratio is 1.679 at 5 percent level for a one tailed test.

TABLE 15

Weighted Coefficients -- Mortality Rates -- White Females

Weighted Ordinary Least Squares -- All Variables Linear						
	1970-1971		1972-1973		1974-1975	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
Independent Variable	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.018	1.04	.039	2.03	.028	1.48
APDR	.244	.603	-.268	-.576	-.010	-.031
AGE	-.003	-.228	.002	.212	-.008	-1.73
AMD	-.015	-.892	.003	.155	.010	.798
NLIS	.020	1.50	.027	1.72	.011	.991
TYPCON	.005	.268	-.008	-.487	-.008	-.627
MUNHT	-.665-05	-.574	-.365-05	-.362	-.692-05	-1.23
URR	-.014	-1.09	-.017	-1.58	-.019	-1.69
GCPC	.642-03	3.92	.387-03	2.63	.372-03	2.98
DL	-.005	-.396	-.014	-.980	-.007	-.581
INSP	-.026	-1.70	-.004	-.272	-.007	-.537
INCR	-.347-04	-1.17	-.742-05	-.266	-.809-05	-.352
HOSP	.026	.197	.035	.245	-.020	-.176
UN	-.003	-.567	.002	.274	-.004	-1.00
WFE	.335-03	.000	-.020	-.856	.002	.105
Constant	.162		.344		.242	
Adj. R ²	.582		.463		.478	
F*	5.09		3.53		3.68	

*F-ratios are significant at 1 percent level. The critical t-ratio is 1.679 at 5 percent level for a one-tailed test.

TABLE 16

Weighted Coefficients -- Mortality Rates -- Non-white Males

Weighted Ordinary Least Squares -- All Variables Linear						
	1970-1971		1972-1973		1974-1975	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
Independent Variable	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.315	1.51	.456	1.62	.366	1.46
APDR	-4.04	-.779	1.25	.176	5.17	1.23
AGE	-.138	-.999	.004	.045	-.014	-.207
AMD	.064	.339	-.144	-.623	.011	.063
NLIS	.245	1.47	.259	1.20	.262	1.65
TYPCON	-.259	-1.19	-.176	-.745	-.183	-.985
MUNHT	.599-04	.443	.640-04	4.95	.898-05	.126
URR	.076	.448	.026	.155	-.076	-.444
GCPC	.005	2.69	.003	1.81	.002	1.44
DL	-.087	-.590	-.041	-.239	-.051	-.399
INSP	.078	.418	.023	.095	.027	.152
INCR	-.449-03	-1.40	-.594-03	-1.77	-.367-03	-1.39
HOSP	1.13	.612	.185	.077	.705	.390
UN	-.083	-1.24	-.080	-.652	-.010	-.170
OME	.129	2.01	.152	1.74	.135	2.12
Constant	1.892		-1.184		.1349	
Adj. R ²	.211		.08		.222	
F*	1.73		1.25		1.78	

*F-ratios not significant

TABLE 17

Weighted Coefficients -- Mortality Rates -- Non-white Females

Weighted Ordinary Least Squares -- All Variables Linear						
	1970-1971		1972-1973		1974-1975	
	Period 1 (n=50)		Period 2 (n=50)		Period 3 (n=50)	
Independent Variable	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.144	1.51	.187	1.61	.162	1.73
APDR	-.239	-1.03	-3.67	-1.17	-.468	-.294
AGE	-.017	-.268	.002	.045	.300-03	.000
AMD	.083	.985	.082	.810	.021	.359
NLIS	.108	1.43	.156	1.66	.063	1.08
TYPCON	-.045	-.458	-.074	-.715	-.040	-.576
MUNHT	-.536-04	-.880	-.241-05	-.427	-.125-04	-.465
URR	-.008	-.110	-.044	-.598	-.002	-.032
GCPC	.001	1.70	.001	1.68	.740-04	1.41
DL	.942-03	.000	-.042	-.566	-.018	-.369
INSP	.041	.050	.048	.481	.051	.787
INCR	-.280-03	-1.94	-.149-03	-1.01	-.112-03	-1.13
HOSP	-.336	-.406	.657	.648	-.020	-.032
UN	-.026	-.841	-.009	-.020	-.016	-.762
OFE	.100	2.92	.115	2.31	.083	2.70
Contant	-.7297		-1.175		-.875	
Adj. R ²	.182		.093		.076	
F*	1.608		1.27		1.22	

*F-ratios are not significant.

TABLE 18

Regression Coefficients -- Pooled Data 1970-75

Weighted -- Whites

Independent Variable	White Males (n = 150)		White Females (n = 150)	
	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.085	3.61	.028	2.56
APDR	-.561	-1.11	-.095	-.470
AGE	-.020	-2.61	-.003	-.754
AMD	.035	1.66	-.005	-.523
NLIS	.044	2.63	.023	3.16
TYPCON	-.068	-3.61	-.002	-.252
MUNHT	-.256-04	-2.90	-.624-05	-1.44
URR	-.053	-4.53	-.018	-3.16
GCPC	.002	9.18	.468-03	6.34
DL	.006	.374	-.010	-1.45
INSP	-.017	-.893	-.012	-1.43
INCR	-.369-04	-1.14	-.195-04	-1.43
HOSP	.057	.651	-.017	-.389
UN	.982-03	.158	-.002	-.703
Year 72-73	-.035	-1.44	-.009	-.784
Year 74-75	-.100	-3.07	-.030	-1.94
WME-WFE	-.058	-4.70	-.008	-1.29
Constant	.9407		.3118	
Adj R ²	.742		.616	
F*	26.25		13.56	

*F-ratios significant at 1 percent level. The critical t-ratio at 5 percent level is 1.64 for a one-tailed test.

TABLE 19

Regression Coefficients -- Pooled Data 1970-75

Independent Variable	Weighted -- Non-Whites			
	Non-White Males (n = 150)		Non-White Females (n = 150)	
	Regression Coefficient	t-Ratio	Regression Coefficient	t-Ratio
LIQPR	.392	2.53	.222	2.89
APDR	1.56	.495	-2.85	-1.83
AGE	-.004	-.084	.005	.205
AMD	-.013	-.094	.099	1.55
NLIS	.373	3.24	.170	3.00
TYPCON	-.205	-1.50	-.045	-.671
MUNHT	.960-05	.155	-.510-04	-1.65
URR	-.027	-.322	-.059	-1.44
GCPC	.004	3.69	.001	2.49
DL	-.089	-.985	-.032	-.725
INSP	.030	.230	.002	.031
INCR	-.532-03	-2.82	-.105-03	-1.14
HOSP	.851	1.31	.445	1.39
UN	-.055	-1.29	-.011	-.525
Year 72-73	.115	.694	.116	1.42
Year 74-75	.052	.223	.129	1.12
OME-OFE	.142	3.48	.086	3.63
Constant	-.5993		-1.381	
Adj R ²	.425		.365	
F*	6.43		5.18	

*F-ratios significant at 1 percent level. Critical t-ratios at 5 percent level is 1.64.

BIBLIOGRAPHY

- Barsby, S. L., and Marshall, G. L. "Short-Term Consumption Effects of a Lower Minimum Alcohol-Purchasing Age." Journal of Studies on Alcohol, 38 (1977).
- Berry, R. E., Jr. and Boland, J. P. The Economic Cost of Alcohol Abuse. New York: The Free Press, 1977.
- Blane, H. T., and Hewitt, L. E. "Alcohol and Youth: An Analysis of the Literature, 1960-1975." A report prepared for the National Institute on Alcohol Abuse and Alcoholism, March, 1977.
- Blomquist, Glenn. "Value of Life: Implications of Automobile Seat Belt Use." Journal of Political Economy (1979).
- Borkenstien, R. F., Crowther, R. F., Shumate, R. P., Ziel, W. B., Zylman, R. The Role of the Drinking Driver in Traffic Accidents (The Grand Rapids Study). 2nd ed., 1974.
- Cucchiaro, S. J., Ferreira, J. Jr., and Sicherman, A. "The Effect of the 18-year-old Drinking Age on Auto Accidents." Cambridge: Massachusetts Institute of Technology, Operations Research Center, 1974.
- Douglass, R. L. "The Consequences of Lower Legal Drinking Ages on Alcohol-Related Crash Involvement of Young People." Journal of Traffic Safety Education, 2 (1977).
- Douglass, R. L. "The Effect of the Lower Legal Drinking Age on Youth Crash Involvement." 260 pp. Ph.D. dissertation, University of Michigan; 1974. (University Microfilms No. 75-672).
- Douglass, R. L. and Filkings, L. D. "The Effect of Lower Legal Drinking Ages in Youth Crash Involvement." Final summary report. 10 pp. Washington DC; U.S. National Highway Traffic Safety Administration, 1974.
- Edwards, Linda N. "An Empirical Analysis of Compulsory Schooling Legislation, 1940-1960." Journal of Law and Economics, April 1978.

- Edwards, L. N., and Grossman, M. "Adolescent Health, Family Background and Preventive Medical Care." National Bureau of Economic Research Working Paper No. 398, Oct., 1979.
- Fingerman, P. W., Levine, J. M., and Eisner, E. J., "Youth, Alcohol, and Speeding: Their Joint Contribution to Highway Accidents." U.S. Department of Transportation, May 1977. (DOT H5-802-356).
- Fuchs, V. R.; Michael, R. T.; and Scott, S. R. "A State Price Index." National Bureau of Economic Research Working Paper No. 320, February 1979.
- Fuchs, V. R., and Leveson, I. "Motor Accident Mortality and Compulsory Inspection of Vehicles." Journal of the American Medical Association, 201 (1967).
- Gavin-Jobson. The Liquor Handbook. Published annually.
- Goldfeld, S. M., and Quandt, R. E. "Some Tests for Homoscedasticity," Journal of the American Statistical Society, 60 (1965).
- Grossman, M. The Demand for Health: A Theoretical and Empirical Investigation. New York: Columbia University Press for the National Bureau of Economic Research, 1972.
- Hammond, R. L. "Legal drinking at 18 or 21--Does it Make any Difference?" Journal of Alcohol Education, 5, 1972.
- Johnston, J. Econometric Methods. New York: McGraw-Hill, 1972.
- MICAP RECAP Report No. 35. Michigan Council on Alcohol Problems. Lansing, Michigan: 14, August 1973.
- National Safety Council. Accident Facts, Various years.
- Peltzman, Sam. "The Effects of Automobile Safety Regulation," Journal of Political Economy, 83 (1975).
- Perrine, M. W., Waller, J. A. and Harris, L. S. "Alcohol and Highway Safety: Behavioral and Medical Aspects." Prepared for the U.S. National Highway Traffic Safety Administration, contract no. FH-11-6609 and FH-11-6899, September 1971; final report. (DOT HS-800, 599).
- Pindyck, R. S., and Rubinfeld, P. L. Econometric Models and Economic Forecasts. New York: McGraw-Hill, 1976.

- Rechal, J. V., et al. "A National Study of Adolescent Drinking Behavior, Attitudes and Correlates."
(Prepared for National Institute on Alcohol Abuse and Alcoholism.) Springfield, Virginia: U.S. National Technical Information Services, 1975.
- Room, R. A. "Evaluating the Effect of Drinking Laws on Drinking. In Drinking edited by John Ewins and B. A. Rouse. Chicago: Nelson Hall, 1978.
- Schmidt, W. and Kornaczewski, A. "The Effect of Lowering the Legal Drinking Age in Ontario on Alcohol-Related Motor Vehicle Accidents," pp. 763-770. In: Israelstam, S. and Lambert, S., eds. Alcohol, Drugs, and Traffic Safety. Proceedings of the Sixth International Conference on Alcohol, Drugs and Traffic Safety, Toronto, 8-13 Sept. 1974, xvii + 939 pp. Toronto; Alcoholism and Drug Addiction Research Foundation of Ontario; 1975.
- Simon, J. L. "The Price Elasticity of Liquor in the U.S. and a Simple Method of Determination." Econometrics, 34, No. 1 (January 1966).
- Smart, R. G., and Schmidt, W. "Drinking and Problems from Drinking after a Reduction in the Minimum Drinking Age." British Journal of Addiction, 70 (1975).
- Smart, R. G., and Goodstadt, M. S. "Effects of Reducing the Legal Alcohol-Purchasing Age on Drinking and Drinking Problems." Journal of Studies on Alcohol, 38, No. 7 (1977).
- Tax Toundation, Inc., Facts and Figures of Government Finance, various issues.
- U.S. Bureau of the Census. Statistical Abstract of the United States, various issues.
- U.S. Federal Highway Administration. Highway Statistics, published annually.
- Wagenaar, A. C. "Effects of an Increase in Drinking Age." Journal of Public Health Policy (1981).
- Waller, P. F. "Drinking and Highway Safety." In Drinking edited by John Ewing and B. A. Rouse. Chicago & Nelson Hall, 1978.

- Whitehead, P. C., Craig, J., Langford, N., MacArthur, C. and Stanton, B. "The Impact of the Change in the Drinking Age on the Collision Behaviour of Young Drivers," pp. 771-774. In: Israelstam, S. and Lambert, S., eds. Alcohol, drugs, and traffic safety. Proceedings of the Sixth International Conference on Alcohol Drugs and Traffic Safety, Toronto, 8-13 Sept. 1974. xvii _ 939 pp. Toronto; Alcoholism and Drug Addiction Research Foundation of Ontario, 1975.
- Williams, A. F., Rich, R. F., Zador, P. L. and Robertson, L. S. "The Legal Minimum Drinking Age and Fatal Motor Vehicle Crashes." Journal of Legal Studies, 4 (1975).
- Zylman, R. "Fatal Crashes Among Michigan Youth Following Reduction of the Legal Drinking Age." Journal of the Studies on Alcohol, 36 (1975).