Reexamination of Impact of Drinking Age Laws on Traffic Accidents in Illinois

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Previous studies of the impact of drinking age laws on traffic accidents have often used statistical techniques or short data sets that can lead to misleading conclusions. Studies generally have focused on fatalities or surrogate variables or both. Using autoregressive integrated moving average techniques and total accidents by month over a 20-year period, the experience in Illinois is reexamined. The lower drinking age in Illinois from October 1973 to January 1980 was responsible for an increase of more than 5,000 accidents per month, a 14 percent increase. When the age was raised back to 21 in 1980, the figures reversed a similar amount. More than 1,000 additional 18- and 19-year-old drivers were involved in accidents each month with the lower age limit, a 20 percent increase. It was also found that total monthly property-damage-only accidents were highly positively correlated with wet or snowy pavement and negatively correlated with dry pavement; fatal accidents behaved in the opposite way. The techniques used can be used to analyze the impact of other public policies on accidents.

Government policies are enacted to accomplish goals. Whether they are successful is typically difficult to determine. In the scientific world, variables can be controlled precisely; in the real world, many influences apply simultaneously. Whether the impact of a public policy can be sorted out from the dynamic interaction of other variables is problematic.

One area that has been studied for some time is the effect on traffic accidents of changes in the minimum drinking age. In the early 1970s, a number of states lowered the minimum age in response to the trend of promoting adulthood at an earlier age. This trend was in conjunction with the lowering of the voting age to 18 in 1971 and the involvement of those under 21 in the armed forces during the Vietnam War. States subsequently reassessed their policies, because alcohol-related accidents in this age group skyrocketed. This reversal was reinforced at the federal level by an amendment to the Surface Transportation Assistance Act of 1982 to withhold federal highway funds after mid-1986 from any state with a minimum drinking age under 21.

The impact on traffic accidents of changes in the drinking age in Illinois was studied. There are a number of motivations for this study. First, many of the statistical techniques used in previous research are suspect. Second, enough time has passed to allow for a substantial number of observations after the policy enactment. Third, most studies have researched the impact of either the lowering or the raising of the drinking age; both are combined in this effort. Fourth, studies have differed in their focus: the majority have used driver fatalities; some have concentrated on injuries, injuries and fatalities, or all accidents. Because of the difficulty in measuring alcohol involvement, proxy or surrogate variables have been employed. The accuracy of these measures is of interest.

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THE ILLINOIS SITUATION

In October 1973, Illinois lowered the minimum legal drinking age for beer and wine from 21 to 19. In addition, home rule laws made it possible for some jurisdictions to allow purchase of all alcoholic beverages at a lower age (*1*). In January 1980 the uniform statewide drinking age of 21 was restored.

A data set suitable to analyze the impact of these changes is compiled monthly by the Illinois Department of Transportation (IDOT) (*2*). For the entire state from 1970 to mid-1989, traffic accident totals (also broken down by fatal, injury, or property damage only), age of drivers involved, and road conditions were selected. The state totals came from police accident reports filed for all accidents with fatalities, injuries, or property damage over a dollar limit (currently $250).

As would be expected, accident figures show much month-to-month variation. In Table 1, the mean, standard deviation, minimum, and maximum values are presented. The age breakdown by IDOT is less than ideal: 11 brackets are used; 18- and 19-year-old drivers are combined as well as those aged 20 through 24.

PREVIOUS RESEARCH

A survey by the Government Accounting Office (GAO) (*3*) located 32 studies on raising the drinking age and traffic accidents, of which 14 were summarized. Many of these were before-and-after comparisons of ratios, often using as little data as 1 year before with 1 year after. Such short time periods make it virtually impossible to separate potential impacts of other variables (rival causes). Attributing all of the changes in the dependent variable to a single causal variable is at best misleading and at worst incorrect. The classic example of such an error was pointed out by Campbell and Ross (*4*) in their study of a Connecticut speeding crackdown: politicians attributed all of a 1-year decline in fatalities to their policy, but it was determined that the decline may have been due to nothing more than a regression to the mean. The year before had seen an unusually high fatality rate; the decline would have been likely to occur with or without the crackdown.

Use of ordinary least squares (OLS) regression analysis in many studies for longer time-series data is also subject to misinterpretation. Using a time series, the inherent OLS as-

TABLE 1 MONTHLY ILLINOIS TRAFFIC ACCIDENT STATISTICS, 1970–1989 (*2*)

Variable	Mean	Standard Deviation	Minimum	Maximum
Total Accidents	40,475	7,065	27,998	84,153
Fatal Accidents	144	33	73	220
Injury Accidents	9,572	1,386	6,506	14,704
Property Damage Accidents	30,760	6,300	21,227	72,360
18-19 Year Old Drivers	5,038	1,218	3,010	11,991
20-24 Year Old Drivers	11,378	2,327	7,688	26,750
25-34 Year Old Drivers	16,479	3,376	10,406	37,605

sumption of uncorrelated error terms is routinely violated (*5,6*). As a result, estimated variances of coefficients are too small, making variables appear significant when they may not be. Most time series have trends (regular or seasonal or both) that need to be removed or modeled (*7*). OLS trend estimates are sensitive to outliers and cannot be estimated with accuracy. To have any reliability, studies using before-and-after or OLS techniques must also include controls—either other age groups or other states.

Traffic accident data are likely to contain patterns of autocorrelation (*8*). If a relatively long series is available, the techniques of Box et al. (*9,10*) provide a superior method to prepare the data for impact analysis (*7*). Comparative studies have found that in most cases these techniques more accurately account for regularities in time series than do alternative strategies of analysis (*11*). This approach is particularly appropriate for identifying significant shifts in accident involvement associated with legal changes independent of observed regularities in the history of the dependent variable.

However, a number of studies using this approach have had relatively few observations after a policy intervention. For example, Hilton (*8*) and Maxwell (*12*) used 12 monthly observations, and Wagenaar (*11*) used 12 months in 1 state and 25 in another. Again, this shortness increases the possibility that other influences will be misconstrued as the interventions. In most states, the after intervention period (higher drinking age) was a time of pervasive awareness and concern about drinking and driving. Police activity was increased and stronger penalties were passed. Because these time periods ran coincidentally, it might be incorrect to attribute any changes to the drinking age alone. A longer after period would allow more confident conclusions. For this study, 45 months before, 75 months during, and 103 months after are available.

All of the studies analyzed in the GAO report (*3*) examined the impact of increases in the drinking age. The report cites a list of works that looked at the result of lower drinking ages, but all such reductions occurred before 1975. GAO believed that data and analytical techniques at the time were less sophisticated and that the issue was less relevant to policy. With a longer time period, and a state that lowered and then raised the drinking age, one dummy variable can account for the presence and absence of a policy (e.g., lower drinking age) rather than two separate intervention variables.

The focus variable for measuring the impact of changes in the drinking age in previous literature has varied considerably (*3*). Direct indications of drinking may come from police observations and tests and in the case of fatalities, coroner's reports. Police observations can lead to bias, because police judgment of intoxication can be subjective and reporting can be incomplete. A coroner's report is more objective, but it constrains impact analysis to accidents involving driver fatalities.

A common proxy for alcohol involvement is the three-factor surrogate: male driver, single-vehicle accident, at night. This measure has been popular, because the probability is above average that crashes meeting these conditions involve alcohol. But this measure will be reliable only to the extent that the ratio of alcohol-related surrogates to the total class of surrogates remains constant (*3*). This measure would attribute to alcohol other causes, such as falling asleep at the wheel (which is certainly more likely at night), acute medical condition, or suicide (*13*). Multiple-car crashes, the impact of "happy hours" earlier in the day, and women's drinking are ignored.

As an alternative, the influence of changes in the drinking age can be measured as a deviation from total accident trends. This measure is suitable with a statistical technique available that uses a long time period to account for trends and other potential influences; it is the one used in this study. Cook and Tauchen (*14*) believed that total accidents would be insensitive to interventions targeted at drunk drivers because such drivers constitute only a small fraction of those involved in crashes. Their view today seems controversial, and the results of this study suggest that the measure is adequate.

MODEL AND RESULTS

The analysis involved the development of an autoregressive integrated moving average (ARIMA) model. This model describes the stochastic autocorrelation structure of the data series and in effect filters out any variance in a dependent variable (e.g., monthly traffic accidents) that is predictable on the basis of the past history of that variable. Remaining variance can then be related to the effects of an intervention variable.

One implication of this approach is that any regular pattern in the dependent variable over time that is similar to the pattern of potential independent variables over time is not considered as a possible causal effect between the variables; such intraseries regularities are filtered out first. This procedure has several advantages (*15*): effects of many exogenous variables are controlled, independent error terms are obtained, and these procedures are a conservative test of the causal connection between two variables.

Examination of the autocorrelation function (ACF) of monthly traffic accidents revealed the presence of regular and seasonal nonstationarity. As a consequence, it was necessary to difference the series both regularly ($Y_t - Y_{t-1}$) and seasonally ($Y_t - Y_{t-12}$). This accounts and corrects for trends from observation to observation and from year to year.

The differenced data were analyzed using the ACF and partial autocorrelation function (PACF) to identify any autoregressive and moving average patterns. The model (0,1,2) $(0,1,1)_{12}$ was identified. Parameters were estimated and are presented in Table 2. The residual ACF and PACF were small and exhibit no patterns. At 24 lags of the ACF, the Ljung-Box Q-statistic was 11.8, which was not significant at the .05 level (the critical chi-square value with 20 degrees of freedom is 31.4). The Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC) suggested that this model was preferable to other models examined. It can be concluded that the model fitting is adequate for the data; the residuals of the model are distributed as white noise.

It is assumed that a change in the drinking age would have an immediate, permanent effect on accidents, which would be reversed if the policy were reversed. The response function is $w_o I_t$, where w_o represents the impact of the change and I_t is 0 when t is less than 46 (October 1973) or greater than 121 (January 1980) and 1 when t is between 46 and 121. The parameter values and model diagnosis statistics for the series including the intervention effects are noted in Table 3. The results suggest that when the lower drinking age was in effect, monthly accidents in Illinois increased by ($w_o =$) 5,700. This was statistically significant ($p < .01$). This represented a 14 percent increase from the mean level of accidents.

One concern with the data is that IDOT changed the threshold for reporting property-damage-only accidents from $100 to $250 in October 1975. Because this could have affected total accidents reported, a second intervention was added, $w_1 J_t$, where J_t is 0 when t is less than 70 (October 1975) and 1 when t is greater than 70. This model produced similar results to the previous one; the w_1 coefficient was not statistically significant for either total accidents or property-damage-only accidents.

It is difficult to compare the results of this study with earlier ones of Illinois because of the differences in dependent variables. However, in all cases the direction of impact is identical. Using an ARIMA model, Maxwell (*12*) estimated that single-vehicle, nighttime, male-driver crashes decreased by 8.8 percent with a higher drinking age. With the same surrogate but using before-and-after comparisons, Schroeder and Meyer (*1*) obtained a slightly higher reduction. Williams et al. (*16*) estimated a reduction in nighttime fatal crashes of 23 percent.

EXTENSIONS

The focus of the research to this point is the impact of the drinking age on the total number of monthly accidents. It is

TABLE 2 ARIMA PARAMETER VALUES AND MODEL DIAGNOSIS STATISTICS, TOTAL ACCIDENTS

Parameter	Order	Value	Std. Error	t-Statistic
Moving Average	1	.41	.06	6.72
Moving Average	2	.36	.06	5.90
Seasonal Moving Average	12	.87	.06	14.99
Constant		-5	16	-0.32

Ljung-Box Q Statistic at 24 lags: 11.8 AIC: 4399 SBC: 4413

TABLE 3 ARIMA PARAMETER VALUES AND MODEL DIAGNOSIS STATISTICS INCLUDING INTERVENTION EFFECTS, TOTAL ACCIDENTS

Parameter	Order	Value	Std. Error	t-Statistic
Moving Average	1	.45	.06	7.20
Moving Average	2	.39	.06	6.35
Seasonal Moving Average	12	.85	.06	15.18
Intervention (W_O)		5767	2007	2.87

Ljung-Box Q Statistic at 24 lags: 15.1 AIC: 4394 SBC: 4412 hypothesized that changes in accidents because of changes in the drinking age were caused by 19- and 20-year-olds. Their changed accident rates would necessarily affect drivers in other age groups. Because accidents can involve two or more drivers, the total number of drivers in accidents exceeds the total number of accidents in a month. Thus, it would be expected that drivers of all ages experience a change in number of accidents. However, it is reasonable to expect that 19- and 20-year-olds would experience a greater percentage effect and other age groups a lesser percentage effect. To test this, the number of drivers involved in accidents in different age brackets was examined. Because 19- and 20-year-olds were not combined by IDOT, three age brackets were selected: 18–19, 20–24, and, as a control group, 25–34. If the hypothesis is correct, the 18–19 group would experience the greatest percentage change, followed by the 20–24 group and finally those 25 through 34.

Using the same time period (1970–mid-1989), the monthly number of 18- and 19-year-old drivers involved in accidents was modeled using ARIMA methods. This was repeated for drivers 20 through 24 and again for those 25 through 34. The $(0,1,2)\ (0,1,1)_{12}$ specification again proved adequate. The response function was $w_o I_t$ as defined earlier. As noted in Table 4, the lower drinking age was associated with more than 1,000 more 18- and 19-year-old drivers' being involved in accidents each month. From an average base of about 5,000, this represented a 20 percent change. Also noted in the table are the percentage changes for the 20–24 group (16 percent) and the 25–34 group (13 percent). The results are consistent with the hypothesis.

Traffic accident literature has indicated the impact of weather as being an exogenous influence (*17–19*). An ARIMA model accounts for seasonal patterns. The influence of weather in this model can be inferred by correlating accidents by type with road surface conditions (dry, wet, or snow and ice). It is noted that the data are monthly totals and not linked to individual accidents. Table 5 shows that dry pavement is associated with fewer property-damage and total accidents but more fatal and injury accidents. Wet pavement is positively correlated with all measures except fatal accidents. Snow or ice has a strong negative association with fatal accidents. This suggests that bad weather is linked to more accidents overall but fewer accidents that involve death or injury.

TABLE 4 ARIMA INTERVENTION EFFECTS FOR DRINKING AGE CHANGES, BY AGE OF DRIVERS INVOLVED IN ACCIDENTS

Age Bracket	Change in Accidents[a]	Percentage
18-19	1005	20
20-24	1835	16
25-34	2153	13

[a] All results statistically significant at the .01 level

TABLE 5 CORRELATIONS BETWEEN ROAD SURFACE CONDITIONS AND TRAFFIC ACCIDENTS

Accident Type	Pavement Condition: Dry	Wet	Snow/Ice
All Accidents	-.14	.39	.62
Fatal Accidents	.55	-.21	-.45
Injury Accidents	.52	.13	-.10
Property Damage Only	-.27	.41	.72

FUTURE RESEARCH

The Illinois data set could be used to examine other areas of interest and controversy. For example, it is alleged that those immediately under the drinking age are more likely to obtain alcohol illegally than those who are farther below (*3*). With an increase of the drinking age to 21, one could examine the percentage reductions in accidents in the younger age groups.

Unusual months of weather could be identified and included in the model for more explanatory power. A variety of other public policies could be examined for their impact. For example, during the past 20 years, laws enacted in Illinois have allowed right turn on red (1973), lowered the maximum speed limit to 55 mph (1974), raised the maximum speed limit on most Interstate highway segments to 65 mph (1987), and mandated the use of seat belts (1985).

In addition, the impacts of economic conditions and gasoline prices and availability are of interest. Changes in the drinking age in bordering states are relevant; for a number of years the lower drinking age in Wisconsin attracted many younger drivers from Illinois. Looking at the short- versus long-term effects of a higher drinking age is a challenge. Wagenaar (*20*) noted that they can differ: short-term impacts can dissipate if below-age drinkers obtain alternative sources of alcohol, or they can be reinforced if new cohorts of younger drivers do not develop patterns of driving after drinking. In Wagenaar's study of Michigan, long- and short-term effects were not very different.

An alternative hypothesis, that raising the drinking age does not reduce fatalities, has been proposed (*21*); more lives are lost among older drivers than are saved among younger drivers. An extension to this considered by Asch and Levy (*22*) was that inexperience in drinking, independent of age, was the major hazard. These results go against the conventional wisdom, but they should be researched further.

SUMMARY AND CONCLUSIONS

The lower legal drinking age that prevailed in Illinois from late 1973 to 1980 caused an increase of more than 5,000 traffic accidents a month, a 14 percent change. This result was obtained using more relevant statistical techniques and avoiding surrogate and proxy variables. The data extended over an unusually long time period for greater validity.

Could changes in accidents be attributable to some other "rival" causes? ARIMA intervention analysis is probably the most appropriate statistical technique for ruling out other causes. Its modeling accounts for (filters out) trends (in population, traffic volumes, safety improvements) and regularities or seasonality (weather, traffic). It asks the question, Was there a statistically significant change in the filtered time series that corresponds with a particular time period? In this case, a change began in October 1973 and ended in December 1979. The data suggest that the answer is yes. Other public policies or events began or ended during this period, but either they were permanent or the time periods did not correspond exactly with the drinking age changes. This increases the confidence in concluding that changes in the drinking age led to changes in the number of accidents.

Reducing traffic accidents saves money. It is estimated that the average traffic accident (a weighted average of fatal, injury, and property damage costs) costs more than $7,000 in 1980 dollars (*23*). Updated to current dollars, the higher drinking age in Illinois saves more than $50 million a month.

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