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The Impact of Underage Drinking Laws on Alcohol-Related Fatal Crashes of Young Drivers

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Abstract

Background—This study used a pre-post design to evaluate the influence on drinking-and-driving fatal crashes of six laws directed at youth aged 20 and younger and four laws targeting all drivers.

Methods—Data on the laws were drawn from the Alcohol Policy Information System data set (1998–2005), the Digests of State Alcohol-Highway Safety Related Legislation (1983–2006), and the Westlaw database. The Fatality Analysis Reporting System data set (1982–2004) was used to assess the ratio of drinking to nondrinking drivers involved in fatal crashes (fatal crash incidence ratio [CIR]). The data were analyzed using structural equation modeling techniques.

Results—Significant decreases in the underage fatal CIR were associated with presence of four of the laws targeting youth (possession, purchase, use and lose, and zero tolerance) and three of the laws targeting all drivers (.08 blood alcohol concentration illegal per se law, secondary or upgrade to a primary seat belt law, and an administrative license revocation law). Beer consumption was associated with a significant increase in the underage fatal CIR. The direct effects of laws targeting drivers of all ages on adult drinking drivers aged 26 and older were similar but of a smaller magnitude compared to the findings for those aged 20 and younger. It is estimated that the two core underage drinking laws (purchase and possession) and the zero-tolerance law are currently saving an estimated 732 lives per year controlling for other exposure factors. If all states adopted use and lose laws, an additional 165 lives could be saved annually.

Conclusions—These results provide substantial support for the effectiveness of under age 21 drinking laws with four of the six laws examined having significant associations with reductions in underage drinking-and-driving fatal crashes. These findings point to the importance of key underage drinking and traffic safety laws in efforts to reduce underage drinking-driver crashes.

Keywords

underage drinking; alcohol impaired driving; laws; beer consumption; drinking drivers involved in fatal crashes; lives saved; Alcohol Policy Information System

After the repeal of prohibition in 1933 (21st Amendment to the U.S. Constitution), each state was given the authority to establish its own minimum legal drinking age (MLDA). Most states established an MLDA of 21. Shortly after the voting age was lowered from 21 to 18 in 1971 (26th Amendment to the U.S. Constitution), many states lowered their drinking age to 18 or 19. By 1983, only 16 states had maintained or raised their drinking age to 21. To reduce drinking and alcohol-related problems among youth in the United States, the federal government

adopted legislation in 1984 that provided a strong incentive—a significant loss of federal highway construction funds—for states that did not adopt a uniform MLDA of 21. By 1988, every state had raised (or maintained) its minimum legal age for both the purchase and public possession of alcohol to age 21 (the two core MLDA laws). In addition, all states and the District of Columbia enacted laws prohibiting the furnishing or selling of alcohol to those younger than age 21; many of the states adopted this law at the same time as the two core MLDA laws. These two core MLDA laws (prohibiting possession and purchase by youth) have been studied extensively over the past 25 years and considerable evidence exists that such laws can influence underage drinking-and-driving fatalities (Arnold, 1985; Decker et al., 1988; O'Malley and Wagenaar, 1991; Ponicki et al., 2007; Shults et al., 2001; Toomey et al., 1996; Voas et al., 2003; Wagenaar and Toomey, 2002; Williams et al., 1983; Womble, 1989). Between 1988 and 1995, alcohol-related traffic fatalities for youth aged 15 to 20 declined 47%, from 4,187 to 2,212, with considerable variability in these declines between the states (NHTSA, 2007).

To support the two core MLDA laws and further enhance their underage alcohol prevention programs, states have enacted other legislation targeting access to alcohol by youth, adults who provide alcohol to youth, and the prevention of impaired driving by youth. For example, laws that address keg registration, the use of fake identification, and the minimum age for alcohol servers/sellers seek to make it more difficult for youth to obtain alcohol from licensed alcohol outlets and have been adopted by many states. Other laws have been enacted that focus on preventing youth from drinking and driving. One such law is zero tolerance (ZT) that makes it an offense for drivers aged 20 and younger to operate a vehicle with any amount of alcohol in their systems (blood alcohol concentration [BAC] > .00). ZT laws have been shown to be effective in reducing youthful alcohol-related fatal crashes (Hingson et al., 1994; Hingson et al., 1992; Voas, Tippetts and Fell, 2003). Some provisions of recent graduated driver licensing (GDL) laws have night restrictions on driving by youth to reduce the risk of drinking and driving, which occurs mostly at night. Although GDL laws with night restrictions may not strictly be underage drinking laws, their clear intent is to reduce underage drinking and driving and were therefore included in our expanded laws. Use and lose laws, which authorize the suspension of driving privileges for underage alcohol violations (i.e., purchase, possession, or consumption of alcohol), provide meaningful sanctions for youth who violate the MLDA laws. Social host laws target those who host underage drinking parties. All of these additional laws were designed to strengthen the two core MLDA-21 laws and increase states' alcohol prevention efforts to protect youth from the harm associated with underage drinking.

Despite the promise of such laws, however, considerable public ambivalence and compromise with opponents has resulted in substantial variation between states in the comprehensiveness of their underage drinking legislation and the exceptions allowed in their laws. For example, although all states make it unlawful for an underage person to possess alcohol, it is legal in some states for an underage person to consume alcohol. In some states, youth are allowed to patronize bars and taverns, despite not being allowed to purchase alcohol. Further, some states have ZT laws that are unenforceable because police officers cannot take a youth into custody or transport him/her to the police station for an alcohol breath test unless they can demonstrate (i.e., have probable cause) that the youth has a BAC higher than the adult illegal limit of .08 BAC (Ferguson et al., 2000). Not all states have graduated driver licensing (GDL) laws, and some states do not have provisions in them restricting unsupervised driving at night when alcohol is most likely to be a factor (Williams and Preusser, 1997).

Although some progress in reducing the harm from underage drinking has been made (Wagenaar and Toomey, 2002), drinking by young people still remains a significant public safety problem. The variability in the strengths and limitations of the states' MLDA laws, as well as the variation in the resources dedicated to their enforcement, produces different levels

of deterrence. Thus, the extent to which states should devote resources to controlling alcohol sales and consumption by young people remains an under-researched but important policy question, at least at the state and local levels. In our earlier study (Fell et al. 2008), the distribution of 16 underage drinking laws across states was documented and their relative strengths were assessed in each state. After attempting to control for various potentially confounding factors, we found that the existence and/or strength of three of these laws was significantly associated with reductions in underage drinking drivers in fatal crashes. The strength of the law making it illegal to use a fake identification to purchase alcohol was associated with reductions in the percentage of underage drinking drivers in fatal crashes (-7% ; $p<.05$). In that same study, an analysis of variance using fatal crash data from 1982 to 1990 found that the existence of the two core MLDA-21 laws was associated with a national 11% reduction in the ratio of drinking to nondrinking underage drivers in fatal crashes.

Public policy officials need to recognize that the MLDA-21 is an interrelated multifaceted set of legal provisions. At its foundation are the 2 core laws, with at least 14 expanded laws, directed at preventing underage drinking. There is a current movement to lower the drinking age from 21 to 18 (Wasley, 2007). If the drinking age is lowered in any state, it will likely affect not only the two core MLDA laws, but also most of the related laws. In other words, if the age for possession and purchase of alcohol is lowered to 18, it would seem that the laws for consumption, zero tolerance for driving, use and lose, and furnishing or selling should also be lowered to 18. Such action would also be expected to weaken associated alcohol policies, such as restrictions on alcohol advertising to persons younger than age 21. Further, it has been recently demonstrated in New Zealand that lowering the legal drinking age results in increased consumption by youth below the legal age limit via a “trickle down” effect which is associated with increases in youth crash involvements and crash injuries (Kypri et al., 2006).

In addition to underage drinking laws, past research has shown that other impaired driving and traffic safety laws also significantly affect numbers or rates of drinking drivers of all ages involved in fatal crashes. In the 1970s and early 1980s, states began adopting laws making it illegal per se to drive with a BAC that was equal to or exceeded 0.10g/dl. Pre- and post-law studies in individual states showed that these per se laws were effective in reducing alcohol-related fatal crashes (Klein, 1989; Voas et al., 2000; Zador et al., 1988). In the 1990s, many states lowered their illegal per se limits to .08 BAC, and in 2000, the U.S. Congress passed a bill encouraging states to adopt the .08 BAC standard or lose federal highway construction funds. By 2003, all 50 states and the District of Columbia had adopted .08 BAC as illegal per se for drivers of all ages. Numerous studies have shown that lowering the illegal per se law from .10 to .08 has been effective in reducing alcohol-related traffic fatalities (Bernat et al., 2004; Dee, 2001; Hingson et al., 1996, 2000; Johnson and Fell, 1995; Shults et al., 2001; Tippetts et al., 2005; Voas et al., 2000; Wagenaar et al., 2007). Administrative license revocation (ALR) laws that allow for driver's licenses to be automatically and administratively suspended for drivers exceeding the per se limit (Klein, 1989; Shults et al., 2001; Voas et al., 2000; Wagenaar and Maldonado-Molina, 2007; Zador et al., 1988) and the adoption of seat belt laws, especially laws allowing primary enforcement whereby an officer can stop the vehicle if the driver is observed to be unbelted (Voas et al., 2000; Voas et al., 2007), have also been shown to be effective in reducing alcohol-related traffic crash fatalities. Underage drinking and impaired driving by youth are thus likely to be influenced not only by alcohol policies and traffic safety laws targeting youth, but also by those laws directed at the general driving population.

This study of these laws used a pre- and post-law design and controlled for a larger number of covariates than previous research. Our goal was to examine which laws that target youthful drivers and which laws that affect drivers of all ages are effective in reducing alcohol-related crash fatalities among young people. Specifically, the study had two primary objectives: (1)

to determine if the enactment of six MLDA-21 laws was associated with reductions in the rate of underage drinking to nondrinking drivers involved in fatal crashes after the effective date, and (2) to determine if the implementation of other key drinking-and-driving laws and socioeconomic conditions in the states had an effect on fatal crashes involving underage drinking drivers.

METHODS

Our pre- and post-law design used data covering a 23-year period from 1982 through 2004. We selected six underage drinking laws for analysis because we could obtain dates when they became effective in each state: (1) a law making it illegal for youth aged 20 or younger to publicly possess alcohol, (2) a law making it illegal for youth aged 20 or younger to purchase alcohol, (3) a law mandating that beer kegs be registered to the purchaser, (4) ZT for alcohol in drivers aged 20 or younger, (5) GDL with night restrictions for novice drivers (intended to reduce the risk of underage drinking and driving), and (6) a use and lose law resulting in a driver's license suspension for an alcohol violation for youth aged 20 or younger. We selected four general impaired-driving and traffic safety laws because there is substantial evidence of their effectiveness with drivers of all ages: ALR for impaired driving; .10 BAC while driving is illegal per se; .08 BAC while driving is illegal per se; and mandatory seat belt laws (secondary and upgrades to primary enforcement). We already had the effective dates in the states for these general laws. Past research indicated that sobriety checkpoints (Shults et al., 2001), beer consumption per capita (Voas et al., 2000, 2003), employment rates (Voas et al., 2000; Voas et al., 2003), and vehicle miles traveled per licensed driver (O'Neill and Kyrychenko, 2006; Voas et al., 2000, 2003) also affect the ratio of drinking drivers to nondrinking drivers in fatal crashes.

Data Sources

Underage Drinking Laws—The primary source of data for underage drinking laws in the states is the National Institute on Alcohol Abuse and Alcoholism (NIAAA) Alcohol Policy Information System (APIS) data set (1998–2005). The National Highway Traffic Safety Administration's (NHTSA's) Digest of Impaired Driving and Selected Beverage Control Laws (NHTSA, 2006a) was also used to obtain more detailed information on ZT laws. For the GDL law, information from the Insurance Institute for Highway Safety (IIHS, 2006) was used. Effective dates for the two core underage drinking laws and the ZT law were obtained from NHTSA's Digests of State Alcohol Highway Safety Related Legislation (NHTSA, 1983-2006). The possession and purchase laws are core MLDA-21 laws; their effective dates were the same, so they were treated as one law. For the keg registration and use and lose laws, legal analysis using the Westlaw database (http://web2.westlaw.com/signon/default.wl?fn=_top&rs=WLW8.08 &vr=2.0&bhcp=1) yielded the effective dates from each state statute. The IIHS database on licensing systems for young drivers provided effective dates for GDL laws with night restrictions for the intermediate or provisional license phase.

Adult Drinking-Driving Laws—The primary sources for key impaired-driving laws in the states are NHTSA's Digests of State Alcohol Highway Safety Related Legislation (NHTSA, 1983-2006). The effective dates for seat belt laws were obtained from NHTSA's *Summary of Vehicle Occupant Protection Laws* (NHTSA, 2006b).

During the full years each specific underage drinking and adult drinking-driving law was in effect, the variable representing that law was coded as “1” and during the years the law was not in effect it was coded as “0”. If a law went into effect sometime during the year, the variable representing it was coded as a proportion reflecting how much of the year it was in existence.

For example, a law effective on April 1, 1998 would have been coded as 0.75 and one effective on July 1, 1998 would have been coded as 0.5 for that year. For both of the example laws, the pre-1998 years would have been coded as 0 and the post-1998 years would have been coded as 1.

Covariates—The frequency of sobriety checkpoints was taken from previous research conducted by Fell, Ferguson, Williams, and Fields (2003). In that study, interviews with state police and other state officials during the year 2000 were used to gather information on the number of checkpoints conducted in the previous year. We used reported frequency of sobriety checkpoints from that study and coded the enforcement variable as: “0” if sobriety checkpoints are illegal and/or the State did not conduct them; “1” if the State conducted checkpoints infrequently (e.g., only during holiday periods); “2” if the State conducted checkpoints monthly or weekly. Per capita beer consumption rates (for the population aged 15 years and older) in the states were obtained from the NIAAA's Alcohol Epidemiologic Data System (Lakins et al., 2007), [un]employment rates were obtained from the U.S. Bureau of Labor Statistics' online area statistics public database (2008), and vehicle miles traveled (VMT) and licensed driver data were obtained from the online public databases of the Federal Highway Administration (FHWA), U.S. Department of Transportation (Office of Highway Policy Information, 2007).

Traffic Fatalities—Annual state-level data from NHTSA's Fatality Analysis Reporting System (FARS) from 1982 to 2004 were used to determine the number of drinking drivers in fatal crashes (NHTSA, 2007). The FARS is a census of all fatal crashes (i.e., resulting in the death of a participant within 30 days of the crash) occurring on U.S. public roadways and reported to the police. Alcohol involvement was documented through BAC test results collected by police or coroners. Where such data were not available, the BACs of drivers, pedestrians, and cyclists were statistically imputed using crash characteristics (such as police-reported driver impairment) to obtain more complete and accurate alcohol data (Subramanian, 2002). In 2004, measured BACs were available on 64% of fatally injured drivers and 25% of surviving drivers in fatal crashes (NHTSA, 2004). This BAC imputation file is available in FARS for each year after 1981.

Fatal Crash Incidence Ratio (CIR) Measure

Because alcohol-related crashes do not occur in controlled environments, it was important to adjust for external factors not related to alcohol legislation that affect the number of all crashes (Dang, 2008). Some examples of these are population growth and demographic changes, driving exposure (reflected in VMT and indirectly in economic indicators), general changes in vehicle safety (crashworthiness, trends toward driving larger vehicles), weather, and road conditions. Although it was theoretically possible to try to account for the effects of all such factors on alcohol-related crashes individually via covariate techniques, realistically it was impossible to obtain operational measures for all of the known extraneous influences. There are also many other general influences of which we may be unaware. However, because the majority of these potentially confounding factors should similarly affect the risk of non-alcohol-related crashes as they do alcohol-related crashes, using non-alcohol-related crashes as a control group should adjust for most of the extraneous factors that cause deterministic variance within both groups of drivers.

Two approaches to accounting for the control group explicitly as part of the dependent measure involve computing either a proportion or a rate, such as percentage of crashes that are alcohol-involved, or the odds of a driver in a fatal crash being alcohol-positive (i.e., the ratio of crash-involved drinking drivers to crash-involved nondrinking drivers, or the CIR) (Voas et al., 2007). Arithmetically, both the proportion and the odds are closely related. Both use the alcohol counts for the numerator, and both contain the nonalcohol counts in the denominator, but the

proportion also adds the numerator into the denominator (i.e., total counts). For statistical analysis, using the odds (usually log-transformed into log-odds) has several advantages over the proportion:

- Regarding assumptions necessary for parametric inference, the proportion has a markedly nonnormal distribution. The log-odds-ratio, on the other hand, has a normal Gaussian distribution.
- The proportion (or percentage) produces effect size estimates that tend to be biased on the conservative side. This occurs because any change in the counts of the treatment group is captured both in the numerator and in the denominator, washing out a portion of the change relative to a null or contrast condition. Given a static condition (no change) in the reference or contrast group, proportions and percentages understate any changes—in either direction—in the “intervention” or “treatment” group and are therefore too insensitive. In contrast, an odds-ratio directly and explicitly compares changes in the treatment group relative to the control group (i.e., alcohol counts/nonalcohol counts).
- The size of increases/decreases of an odds-ratio are simpler to interpret (e.g., “1.4 times as likely”) than are the “relative percentage of a percent” or “percentage of a proportion” that can be confusing to the public.

The superiority of the CIR as an outcome measure is explained in further detail in Voas et al. (2007).

The Hypothesized Model

The path diagram (Figure 1) represents the model hypothesized for the MLDA analysis. The model is comprised of the following measured variables:

- six laws targeting youthful drivers (GDL with nighttime restriction, use and lose, keg registration, ZT, and possession and purchase [the two core laws treated as one law]);
- four laws targeting all drivers (primary and secondary seat belt laws [treated as one composite seat belt law], .08 BAC per se, .10 BAC per se, and ALR);
- beer consumption per capita (gallons of ethanol);
- employment rates (percent);
- vehicle miles (thousands) traveled per licensed driver;
- enforcement level through the frequency of sobriety checkpoints; and
- two outcome measures (the fatal CIR or ratio of drinking to nondrinking drivers in fatal crashes aged 20 and younger and the ratio of drinking to nondrinking drivers in fatal crashes aged 26 and older [older cohort]).

We purposely avoided using drivers aged 21-25 in case there were any carryover effects of any of the underage drinking laws on this age group.

The model suggests that the two outcomes covary: the ratio of alcohol-positive to alcohol-negative drivers aged 20 and younger and the ratio of alcohol-positive to alcohol-negative drivers aged 26 and older. Furthermore, we assumed all 10 laws directly affect the ratio for those aged 20 and younger, but only the 4 general safety laws and the keg registration law affect the ratio for those aged 26 and older. In addition, beer consumption affects both ratios, but beer consumption is affected by the .08, .10, and ALR laws, and a latent “strong economy” variable represented by the employment rate and VMT per capita. Thus, beer consumption serves as both a predictor and an intermediate outcome in the model.

Also included in the model are components representing the autoregressive parameters for the two FARS outcome measures (these two being the previous year's alcohol ratio for those aged 20 and younger and for the older cohort). The autoregressive components help account for correlated errors within state over time and are the best way to eliminate general "trend" influences that are separate from other measured factors that change over time (e.g., law changes, economic changes, and beer consumption changes). Given that the outcomes are allowed to covary, logic dictates that we allow these to covary, too.

Data Analyses

Structural Equation Modeling—The data were analyzed using Structural Equation Modeling (SEM) techniques in AMOS (Analysis of Moment-Based Structures), which is an SPSS-based package (SPSS Inc. Headquarters, Chicago, Illinois, USA). SEM is a confirmatory technique because the model, which is normally presented in the form of a path diagram, must be specified beforehand. SEM enables the exploration of the causal relationships between variables, both observed (measured) and unobserved or latent (which are linear combinations of observed variables) (Jöreskog, 1966, 1967, 1969). As such, it has become more popular among researchers who are interested in more than the simple nature of relationships between variables that regression analysis provides (e.g., Kuntsche et al., 2008). We had previously used traditional pooled cross-sectional time series regression to model the data (Fell et al., 2008) but theorized that it might also be relevant to use SEM. SEM was deemed advantageous for two reasons: (1) to account more precisely for the differential effects of laws on simultaneous joint outcomes (i.e., the fatal CIRs for those younger than 21 and those older than 25), and (2) to model beer consumption as an intervening variable rather than only as a predictor of the FARS ratio.

The youth outcome is correlated with the older cohort: The FARS ratio measure (fatal CIR) for the older cohort (older than 25) is understandably correlated with the youth outcome measure for the same state and year and, within the same state, tends to change over time similar to the changes in the youth measure.

In our previous analyses (Fell et al., 2008), when the older cohort was omitted, the results may have *overstated* the effects of the law changes (and reduced the ability to explain much of the residual error term that was common to both). Using the adult cohort as a *predictor* of the youth outcome, however, may overcapture the effects of laws that affect both series and incorrectly attribute a large portion of the variance to the adult series, thereby *understating* the effects of the law changes on the youth outcome. By including the older cohort as a *simultaneous* joint outcome that covaries with the youth outcome, the differential effects of the laws can be measured on both outcomes. This approach did not structurally predict the youth outcome from it, and the adult measure did not diminish the effects of the laws as it would have if it were structurally *previous* to the youth, as the laws actually are. This structure is designated in the model by the double-directional arrow on the far right, in Figure 1, linking the residual error terms of the outcomes (res3 and res4).

Per capita beer consumption can serve as an intermediate factor in the model (i.e., as both cause and effect). Per capita beer consumption (rather than wine, liquor, or overall alcohol consumption) has been shown to be highly correlated with the FARS alcohol ratio (fatal CIR) in general (Voas et al., 2007). Leaving it out of the model increases the error terms, both *between-states* (states with fewer crashes also have lower beer consumption) and *within-states* (states in which beer consumption is reduced comparatively more than other states, relative to their own baseline drinking rates, have fewer fatal crashes). Although it would be preferable to use beer consumption measures that are specific to each age group cohort, those measures are not available, so the overall rate for a state must therefore serve as a proxy measure for beer consumption within each component age group.

Similar to the issue of inclusion of the older cohort as a predictor of youth fatalities, the issue with beer consumption was that it also appeared to be correlated to some of the laws, such that using it solely as a predictor of the FARS outcomes may have been wiping out the effects of the laws that covary with beer consumption. Because this SEM has beer consumption as being structurally intermediate (i.e., *between* the laws and the outcomes), we could assess and estimate the *indirect effects* of the alcohol laws on the FARS outcomes as mediated through beer consumption and then filtered through to the outcomes (arrows from laws to beer consumption, and then arrows from beer consumption to the FARS outcomes in Figure 1). We also estimated the *direct effects* of the laws on the FARS outcomes, separately and independently of changes in beer consumption (arrows from those same laws directly to the outcomes in Figure 1).

RESULTS

Direct Effects of Laws

Table 1 presents the estimates, standard errors, and significance levels of coefficients representing the direct relationships between the predictors and outcomes, and the associated effect sizes. Figure 1 presents a graphical display of the relationships. In both Table 1 and Figure 1, all relationships are presented regardless of their significance. However, only the significant and marginally significant paths were retained in the final model. The estimates presented for the nonsignificant paths are those obtained immediately before their exclusion from the model.

For those aged 20 and younger, the results indicated that four of the underage drinking and underage impaired-driving laws were associated with significant decreases in the FARS ratio of drinking to nondrinking drivers in fatal crashes. Specifically, significant decreases in the underage fatal CIR were associated with the implementation of possession and purchase laws (-16% , $p < .001$), the ZT law (-5% , $p = .015$), and the use and lose law (-5% , $p = .026$). The GDL law did not emerge as significantly related to the underage fatal CIR. Contrary to expectations, keg registration was associated with a significant increase in the fatal CIR (12% , $p < .001$). These results are displayed in Figure 2.

Three of the laws targeting the overall driving public were also associated with reductions in the drinking-driver fatal CIR for youth: a secondary seat belt law or adding a primary law (-3% , $p = .041$), the ALR law (-5% , $p = .024$), and the .08 per se law (-8% , $p = .002$). There was a marginally significant downward trend associated with the .10 per se law for the underage group (-7% , $p = .065$). These results are displayed in Figure 3.

Similar findings for the laws targeting all drivers were found for drivers older than 25. For this older cohort, all four laws directed at the general driving public were related to decreases in the fatal CIR—a secondary seat belt law or addition of a primary law (-2% , $p = .016$), the ALR law (-4% , $p < .001$), the .08 law (-6% , $p < .001$), and the .10 law (-4% , $p = .042$). See Figure 4 for a graphical display.

Direct Effects of Other Variables

As expected, the intermediate variable, beer consumption, was significantly and positively associated with alcohol-related fatalities among youth. Every additional gallon of ethanol consumed (per capita) was associated with a 44% increase ($p < .001$) in the underage alcohol-related fatal CIR. As with the youth cohort, beer consumption showed a smaller but statistically significant incremental effect on the fatal CIR for drivers older than age 25, with every additional gallon of ethanol consumed associated with a 28% increase in the fatal CIR ($p < .001$). Based on the average alcohol consumption rates across all states, a 10% increase in the

current levels of per capita beer consumption would be associated with a 4.9% increase in drinking-driver fatal crashes for those aged 20 and younger and an increase of 3.3% in drinking-driver fatal crashes for those aged 26 or older.

Enforcement through sobriety checkpoints evidenced a different pattern of results with the two age groups. Among youthful drivers, enforcement was not significantly related to the fatal CIR; however, for drivers older than 25, enforcement through checkpoints was associated with a small but significant reduction in the drinking to nondrinking fatal CIR (-1% , $p = .004$). See Figure 4.

Regarding the effects of other covariates on the fatal CIR and the influences of laws on the intermediate variable, beer consumption, a number of significant findings emerged. The strength of the state economy was inversely associated with the drinking-driver fatal CIR in both age groups (-3% , $p = .007$ for underage drivers, -3% , $p < .001$ for drivers older than 25). In other words, when and where the economy was improving (defined here as having both the employment rate and the VMT per licensed driver increase), the effect was to reduce the fatal CIR for both the underage and the older age cohorts. This suggests that when economic conditions are good in a state, the increase in driving is greater than the increase in drinking. Consequently, there is a greater increase in nondrinking drivers involved in fatal crashes than for drinking drivers involved in fatal crashes. The .08 law and keg registration laws were both negatively related to beer consumption (-10% , $p < .001$ and -7% , $p < .001$, respectively); in contrast, the ALR law was associated with a 6% ($p < .001$) increase in beer consumption.

Indirect Effects

Table 2 presents the estimates of the indirect effects in the model. These estimates indicate that, even though the direct effect of the keg registration law on both fatal CIRs was positive (an increase), there were also significant negative indirect effects of the keg registration law, through its association with beer consumption, for both the underage (-3%) and the older than 25 (-2%) fatal CIRs. Keg registration laws could conceivably affect both youth and adult alcohol consumption because such laws require adults aged 21 and older to register beer kegs in their names so that they can be tracked back to them. This would occur if a keg were confiscated at an underage drinking party or at a party that results in arrests for fighting, disorderly conduct, or property destruction. Theoretically, these laws should make it more difficult for underage youth to obtain a beer keg and make purchasing a beer keg a bit more onerous for adult drinking parties.

Total Effects

Table 3 presents the resulting total effects when the direct and indirect effects are added, where both exist. As expected, the absolute value of the total effect is smaller than the absolute value of the direct effect when the direct and indirect effects are in opposite directions, and larger when the effects are in the same direction. Table 4 shows the descriptive statistics for the continuous variables used in the analyses. Table 5 shows the number of states with underage and traffic safety laws in each year of the study period.

Estimate of the Lives Saved

Using the most recent 8 years of available FARS data (1998-2005), the period when all of these laws were operating, we estimated the lives saved by the four underage drinking laws that showed significant reductions. The “responsibility” for fatalities in a crash is attributed proportionately among all drivers in that crash according to their BAC levels, with higher BACs deemed more “responsible.” This is based upon the responsibility percentages of drivers in fatal crashes by various BAC levels derived from Terhune et al. (1992). We derived the

following “relative responsibility risk ratios” (relative to the responsibility of drivers with .00 BACs):

BAC of .01–.04=1:1 (same as .00 BAC)
 BAC of .05–.07=2.0:1 (low BAC group)
 BAC of .08+=7.3:1 (high BAC group)

From those calculations during the years 1998 to 2005, there was an average of 2,977 fatalities per year attributable to drivers aged 20 and younger with BACs $\geq$.01. Therefore, using the 16.14% effect size for the two core laws, an estimated 573 lives per year are being saved. Using the 5.07% effect size for ZT laws, an estimated additional 159 lives are being saved per year. If all states adopted use and lose laws (effect size of 5.26%), an additional 165 lives could be saved per year (of which approximately 132 additional lives per year are now being saved in 36 states and the District of Columbia that already have these laws). We estimate that these four laws combined are currently saving an estimated 864 lives each year.

DISCUSSION

These results provide substantial support for the effectiveness of under age 21 drinking laws, with four of the six laws we examined having significant associations with reductions in underage drinking-and-driving fatal crashes. Specifically, the laws associated with purchase/possession, ZT, and use and lose all had direct inverse associations with the underage ratio of drinking to nondrinking drivers involved in fatal crashes. Only GDL with night restrictions and keg registration laws failed to show significant associations with fatal CIR reductions. This does not necessarily mean these laws are not effective (although that is one possible conclusion); it could mean that any effects were not detected in this study using these measures. Fatal crashes represent only a small portion of total crashes and are the most severe outcomes associated with impaired driving. These laws may yet be having an effect on drivers in non-fatal crashes -- but such outcomes were not available for testing in our model.

For GDL, nighttime restrictions for novice drivers (aged 15 to 17) have been found to be effective in reducing underage fatal crash involvement (Williams and Preusser, 1997), but it is still unclear whether the restriction reduces the number of *drinking* drivers aged 20 and younger in fatal crashes. The night restriction may well reduce drinking and nondrinking youthful driver fatal crashes equally by simply reducing their exposure to the increased risks of nighttime driving (which is what this analysis showed). The night restriction generally affects only drivers aged 15 to 17. Drivers aged 18 to 20 involved in fatal crashes are more likely to be drinking drivers than are drivers aged 15 to 17. The specific hours of restriction were also not considered in this analysis. We only considered whether the State had a GDL law with *some* nighttime restriction. Further analyses may show that the specific hours of restriction have an effect on underage drinking drivers.

Contrary to expectations, keg registration was positively and significantly associated with the underage alcohol-related fatal CIR. This means the presence of keg registration laws was associated with an increase in underage drinking fatal crashes. The direct effect of this law, however, was expected to be negative (i.e., with drinking drivers reduced more than non-drinking drivers and thus a lower ratio after the law than before). The counterintuitive effect obtained could have been spuriously caused by the nonrandom assignment of the laws throughout the states and years, resulting in cells that were not representative of the majority of states when the data were broken out across the laws. This problem might have been clarified by stratifying by state, but this was not feasible as there were only 23 longitudinal cases per state (each case being an annual rate for each of the 23 years covered), and the model being

fitted estimated many parameters. The within-state stratified solution to check for a reversal in the keg registration effect would probably risk over-fitting a model that is already approaching the allowable threshold of cases per parameter being estimated. Thus, our only option was to retain the existing model with the counterintuitive keg registration effect. An analysis of indirect effects, however, showed that keg registration had a significant negative indirect effect on the underage fatal CIR (−3%) through its effect on beer consumption, yielding a total effect size of +9%. It is not readily apparent why this unexpected overall effect occurred in the “wrong” direction. Perhaps states that adopt keg registration laws have higher levels of underage drinking and driving. Conversely, keg registration laws that may reduce underage beer keg consumption may also promote the substitution of distilled spirits consumption by youths. The BACs of underage drinkers at beer keg parties may not be as high as the BACs of youth who bring their own alcohol (in many instances, liquor, or an 8-pack of beer) to parties. We have no data to support these possible explanations, but they are worth exploring. We are not aware of any studies of keg registration laws that have shown any impact of the law (see Wagenaar et al., 2005). Keg registration laws are intended to reduce the number of underage drinking parties where kegs of beer are usually consumed. If reductions like that occurred, they did not translate (during this study period of 1982-2004) to a reduction in underage drinking-driver involvements in fatal crashes. It is also possible that keg registration laws are not enforced sufficiently and/or are just not effective in reducing underage drinking and driving. However, more research is needed on the effects of these laws before a clear conclusion can be drawn.

Three of the general impaired-driving and traffic safety laws examined were also significantly associated with reductions in the underage drinking-driving fatal CIR (lowering the illegal BAC limit to .08, ALR, and safety belt usage laws). However, the four underage drinking laws had a greater effect than the impaired-driving laws that apply to drivers of all ages.

Regarding alcohol-related fatal crashes among drivers aged 26 and older, the direct effects of the impaired-driving laws that apply to drivers of all ages were similar to, but less than, their effects on underage drivers. There were significant decreases in the ratio of drinking to nondrinking drivers aged 26 and older associated with all four of the laws targeting drivers in general. Also consistent with the underage drinking driver results, beer consumption was associated with an increase in the fatal CIR of the aged 26 and older drivers. Research has consistently indicated that beer consumption is affected by price. Increases in state and federal excise taxes on beer have been shown to reduce traffic fatalities, particularly those involving young drivers (Chaloupka et al., 1993; Kenkel, 1993; Ruhm, 1996). Keg registration was also positively and significantly associated with the fatal CIR for those aged 26 and older; however, it also demonstrated a significant −2% negative indirect effect through beer consumption resulting in a total effect size of only 2%.

Contrary to expectations, the ALR law was associated with a 6% ($p < .001$) increase in beer consumption. As with the findings for keg registration and the underage fatal CIR, this counterintuitive reversal was likely due to the nonrandom assignment of these laws throughout the states and years, which is always a potential design weakness in public policy evaluation. Again, because of the small number of cases per state, it was not feasible for the analysis to stratify by state. Rather than deleting seemingly spurious coefficients on an ad hoc basis, it is important to present all the results without bias. Thus, our only option was to retain the existing model. Perhaps during the study period, people in States with ALR were drinking as much or more beer, but were not drinking and driving as much. Another explanation could be that in States with ALR laws, fewer people were drinking beer, but the ones who were drinking were consuming more beer.

The reduction in the underage drinking to nondrinking driver crash incidence ratio over time was primarily due to reductions in the number of underage drinking drivers, whereas the number of nondrinking drivers fluctuated around a median value. Conversely, the reduction in the fatal CIR for the older age cohort was influenced by the number of alcohol-negative drivers, which sharply increased over time while the number of alcohol-positive drivers declined only slightly. These findings point to the importance of underage drinking laws and traffic safety laws in efforts to prevent drinking and driving among young people.

There are at least 16 underage drinking laws that have been adopted by some of the states that could have an impact on underage impaired driving. Documented in detail in a previous study (Fell et al., 2008), these were:

- The two core laws applying to youth: (1) possession and (2) purchase
- Three expanded laws applying to youth: (3) consumption, (4) use and lose, and (5) use of a fake ID
- Two expanded laws applying to youth driving: (6) ZT and (7) GDL with night restrictions
- Seven laws applying to providers of alcohol to youth: (8) furnishing or selling, (9) age for on-premise servers, (10) age for off-premise servers, (11) keg registration, (12) responsible beverage service training, (13) retailer support provisions for false ID, and (14) social host liability for underage parties
- One law applying to manufacturers of fake IDs: (15) illegal to produce or transfer fake IDs
- One law applying to state control of alcohol: (16) licensed or state control of retail alcohol distribution

We obtained the legislative effective dates from the states for 6 of the 16 laws. Effective dates for the remaining 10 underage laws are not readily available. Compiling them will likely require comprehensive in-depth legal analysis that we could not conduct with the available resources. However, the dates for the remaining 10 laws should be accessed so that additional analyses of the kind described herein can be conducted. This will help states decide what their legislative agenda should be when it comes to reducing underage drinking and its consequences.

It is important to note some of the limitations associated with this study. First, as with most public policy evaluations, a true experimental design with randomized and fully balanced assignment to conditions was not possible, resulting in an unbalanced distribution of conditions across cases that may be partly determined by unmeasured extraneous factors. The self-selection of a state to a “positive” law condition may reflect a factor (or several) that makes that state unrepresentative of the nation. For these reasons, measures of driving-under-the-influence (DUI) arrest rates are considered ambiguous in a “chicken versus the egg” sense, in that low DUI arrest rates could indicate either poor enforcement efforts or successful deterrence (or, in the case of Utah, a unique environment presenting a low baseline incidence). States that enact a law may be unique in their generally proactive environment (and lower problem incidence) or, conversely, may be desperate because their problem is high relative to other states. Although these potential nonrandom effects might be invoked to explain the counter-intuitive effects for ALR and keg registration, they represent a double-edged sword that might also threaten the validity of findings that were in the expected direction. Because most policy evaluations face this same design limitation, the best that can be accomplished is to account for as many other significant factors as is feasible and to ensure the design is as robust as possible.

A second limitation relates to measurement, including the use of measures that were less than ideal in assessing constructs of interest and the absence of data on relevant variables. For example, rather than being able to access per capita beer consumption by age groups we had to use per capita beer consumption for all adults. It is conceivable that changes in a state's youth rates might be different from the changes in the consumption rates for all ages in that state; however, we believe that adult rates are likely to be reflective of youth rates. Similarly, other economic indicators (e.g., gross domestic product per capita) and state environment measures (alcohol tax rates, sale price/cost measures) would likely have been helpful in accounting for variance in the measures but data for these variables were not readily available.

A third limitation is the relative rarity of the event that produces the outcome measure, fatal crashes. If alcohol involvement were more reliably measured (or imputed) in nonfatal crashes, and if all states made publicly available a high-quality state crash file including nonfatal injury crashes, then a more sensitive and comprehensive outcome measure could be used. As it is, we must make inferences about the alcohol-crash problem with data limited to the most extreme and infrequent events. Despite these limitations, the current study is informative and provides empirical support for underage drinking and impaired driving policies that are consistent with other prior research.

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Figure 1.

Full SEM including all coefficients (regardless of statistical significance). Fit: χ^2 (N= 1122, df =108) = 4041.26, $p < .001$, $\chi^2/df = 37.42$, CFI = .443, NFI = .439, RMSEA=.18

Figure 2.
MLDA-21 Law Effects on Ratio of Age <21 Drinking Drivers to Age <21 Nondrinking Drivers in Fatal Crashes (1982-2004)

Figure 3.
Traffic Safety Law Effects on the Ratio of Age <21 Drinking Drivers to Age <21 Nondrinking Drivers in Fatal Crashes (1982-2004)

Figure 4.
Traffic Safety Law and Enforcement Effects on the Ratio of >Aged 25 Drinking Drivers to
>Aged 25 Nondrinking Drivers in Fatal Crashes (1982-2004)

Table 1

Estimated Coefficient Values and Significance Levels for the Direct Effects

Predictor	B (Estimate)	Effect Size (%)	Standard Error (B)	P-value
Significant paths¹				
Outcome = Natural Logarithm (< 21 FARS ratio)				
Underage drinking laws:				
Possession & Purchase	-0.176	-16.14	0.036	< .001
Zero tolerance	-0.052	-5.07	0.021	0.015
Use & Lose	-0.054	-5.26	0.024	0.026
Keg Registration	0.116	12.30	0.026	< .001
General alcohol/traffic safety laws:				
Composite seat belt	-0.032	-3.15	0.016	0.041
Administrative license revocation	-0.051	-4.97	0.023	0.024
.08 BAC per se	-0.079	-7.60	0.026	0.002
.10 BAC per se	-0.068	-6.57	0.037	0.065
Covariates:				
Beer Consumption	0.367	44.34	0.051	< .001
Economic Strength	-0.030	-2.96	0.011	0.007
Autoregressive Component:				
Lag 1 of Natural Logarithm (< 21 FARS ratio)	0.435		0.02	< .001
Outcome = Natural Logarithm (> 25 FARS ratio)				
Underage drinking law:				
Keg Registration	0.042	4.29	0.013	0.001
General alcohol/traffic safety laws:				
Composite seat belt	-0.019	-1.88	0.008	0.016
Administrative license revocation	-0.037	-3.63	0.011	< .001
.08 BAC per se	-0.065	-6.29	0.013	< .001
.10 BAC per se	-0.037	-3.63	0.018	0.042
Covariates:				
Beer Consumption	0.250	28.40	0.025	< .001
Checkpoint enforcement	-0.014	-1.39	0.005	0.004
Economic Strength	-0.031	-3.05	0.006	< .001
Autoregressive Component:				
Lag 1 of Natural Logarithm (> 25 FARS ratio)	0.577		0.016	< .001
Intermediate Outcome = Beer consumption				
Underage drinking law:				
Keg Registration	-0.077	-7.41	0.015	< .001
General alcohol/traffic safety laws:				
Administrative license revocation	0.061	6.29	0.013	< .001
.08 BAC per se	-0.109	-10.33	0.015	< .001
Latent Factor = Economy				

Predictor	B (Estimate)	Effect Size (%)	Standard Error (B)	P-value
Indicators:				
Vehicle miles traveled per licensed driver	Set to 1			
Employment Rate	0.909	59.71	0.215	< .001
Nonsignificant paths				
Outcome = Natural Logarithm (< 21 FARS ratio)				
Underage drinking law:				
Graduated driver licensing with nighttime restriction		0.10		0.983
Covariate:				
Checkpoint enforcement		-0.90		0.387
Intermediate Outcome = Beer consumption				
General alcohol/traffic safety law:				
.10 BAC per se		2.70		0.218
Covariate:				
Economic Strength		-0.70		0.257

FARS = Fatality Analysis Reporting System

¹ Other significant model components: (1) covariance between error terms (e12 and e13) B (Estimate) = 0.117, $p < .001$; (2) covariance between residuals (res3 and res4) B (Estimate) = 0.017, $p < .001$

Table 2

Estimated Coefficient Values for the Indirect Effects

Predictor	B (Estimate)	Effect Size (%)
Outcome = Natural Logarithm (< 21 FARS ratio)		
Underage drinking law:		
Keg registration	-0.028	-2.76
General alcohol/traffic safety laws:		
Administrative license revocation	0.022	2.22
.08 BAC per se	-0.040	-3.92
Outcome = Natural Logarithm (>25 FARS ratio)		
Underage drinking law:		
Keg registration	-0.019	-1.88
General alcohol/traffic safety laws:		
Administrative license revocation	0.015	1.51
.08 BAC per se	-0.027	-2.66

FARS = Fatality Analysis Reporting System

Table 3

Estimated Coefficient Values for the Total Effects

Predictor	B (Estimate)	Effect Size (%)
Outcome = Natural Logarithm (< 21 FARS ratio)		
Underage drinking law:		
Keg registration	0.087	9.09
General alcohol/traffic safety laws:		
Administrative license revocation	-0.029	-2.86
.08 BAC per se	-0.120	-11.31
Outcome = Natural Logarithm (>25 FARS ratio)		
Underage drinking law:		
Keg registration	0.023	2.33
General alcohol/traffic safety laws:		
Administrative license revocation	-0.022	-2.18
.08 BAC per se	-0.093	-8.88

FARS = Fatality Analysis Reporting System

Table 4

Descriptive Statistics for Continuous Variables Used in the Analysis

Variable	Mean	Standard Deviation	Minimum	Maximum	Range
Ratio of drinking to nondrinking drivers < 21 years old	0.437	0.236	0.07	2.05	1.98
Natural log transform of the ratio of drinking to nondrinking drivers < 21 years old	-0.958	0.514	-2.72	0.72	3.44
Ratio of drinking to nondrinking drivers > 25 years old	0.395	0.128	0.11	1.15	1.04
Natural log transform of the ratio of drinking to nondrinking drivers > 25 years old	-0.978	0.317	-2.23	0.14	2.37
Employment rate (%)	94.245	1.959	81.98	98.00	16.02
Vehicle miles traveled per licensed driver (000's)	13.537	2.468	8.3	29.7	21.4
Per capita beer consumption (gallons of ethanol)	1.311	0.221	0.73	2.18	1.45

Table 5
The Number of States with Underage and Traffic Safety Laws in Each Year: 1983-2004

Year	Underage Drinking Laws					Traffic Safety Laws				
	Possession & Purchase	ZT	Use & Lose	Keg Registration	GDL with Night Restriction	Secondary Seat Belt	Primary Seat Belt	ALR	.08	.10
1983	16	0	6	2	0	0	0	14	0	34
1984	20	0	6	3	0	0	0	19	2	38
1985	32	0	7	3	0	7	3	20	2	40
1986	44	0	7	3	0	23	7	21	2	40
1987	49	0	7	3	0	28	7	21	2	43
1988	51	0	13	3	0	31	7	24	2	43
1989	51	0	17	5	0	33	7	24	3	44
1990	51	2	23	7	0	35	7	29	4	46
1991	51	2	23	7	0	39	8	30	4	46
1992	51	3	24	9	0	41	8	31	5	48
1993	51	7	26	12	0	43	9	33	5	48
1994	51	16	28	15	0	47	9	36	11	49
1995	51	22	29	16	0	48	10	38	13	49
1996	51	29	30	16	1	49	11	40	14	50
1997	51	38	33	16	4	50	14	40	14	50
1998	51	48	33	16	10	50	15	41	16	50
1999	51	51	33	16	21	50	15	42	18	50
2000	51	51	33	16	26	50	18	42	19	50
2001	51	51	35	17	33	50	18	42	21	50
2002	51	51	37	19	35	50	19	42	30	50
2003	51	51	37	21	37	50	21	42	35	51
2004	51	51	37	25	37	50	22	42	47	51

ZT = zero tolerance laws for drivers under age 21; GDL = graduated driver licensing; ALR = administration license revocation; .08 = blood alcohol concentration limit for drivers aged 21 and older; .10 = blood alcohol concentration limit for drivers aged 21 and older