Fuel Efficiency and the Determinants of Traffic Fatalities: A Comparison of Empirical Models

Mark Gius*

Abstract

The present study has three primary purposes. First, this study will attempt to determine the effects of fuel efficiency standards on traffic fatalities; this is a long-running topic of contention in the area of vehicle safety. Second, this study will look at the effects of legal restrictions on traffic fatalities. Once again, there is dispute regarding the potential effects that laws may have on driver behavior. Finally, the present study will compare and contrast three commonly used empirical techniques in order to determine which variables are most robust or consistent in their effects on traffic fatalities. Using data from 48 states over a 23 year time period, the results indicate that fuel efficiency standards have a negative effect on traffic fatalities, irrespective of the type of empirical technique employed. Regarding other pertinent variables, the results of two of the three models suggest that socioeconomic factors, such as the age distribution of the state and per capita alcohol consumption, had much more significant effects on traffic fatalities than state-imposed legal restrictions, such as minimum legal driving ages.

INTRODUCTION

In 1975, Congress passed legislation that established fuel economy standards for all new automobiles sold in the United States. This legislation was enacted in reaction to the Arab Oil Embargo of 1973 and the rapidly escalating gasoline prices that followed. Initial fuel economy standards were set at 18 miles per gallon (mpg) for passenger cars and, at the most, 17.2 mpg for light trucks. Current standards are 27.5 mpg for passenger cars and 20.7 mpg for light trucks.

Ever since the imposition of these fuel economy standards, which are known as the Corporate Average Fuel Economy Standards (CAFE), an ongoing debate has ensued regarding the impact of these standards on traffic fatalities. Auto manufacturers, for example, contended that the only real way to achieve these standards in the early years was to decrease the weights of cars and trucks. According to this argument, these reductions in weight would increase the probability that the occupants of the vehicles would be severely injured or die in traffic accidents. In fact, Noland (2005) noted that one obstacle to increasing fuel efficiency standards has been its potential effect on vehicle safety.

Others, however, countered that, although manufacturers initially may have had to reduce vehicle weights to achieve the required fuel economy standards, advances in engine technology and safety

*Department of Economics, Quinnipiac University, Hamden, CT 06518, Ph: 203-582-8576, Fax: 203-582-8664, E-mail: gius@quinnipiac.edu

design have resulted in vehicles being manufactured today that are not only much more fuel efficient, but also much safer, than the cars of thirty years ago. In addition, many of these advances in engine technology would not have been undertaken without fuel economy standards; the reason for this is because the real price of gasoline fell from the early 1980s to the early 2000s. Hence, auto manufacturers would have had little incentive to improve engine technology, especially in the area of fuel consumption, if it had not been for the fuel economy standards set by the federal government.

In order to properly estimate the effects of fuel efficiency standards on traffic fatalities, a model of traffic fatalities must be devised. As will be noted in this paper, there have been numerous studies on this topic. Unfortunately, few prior studies looked at an all-encompassing model, one that incorporates not only fuel efficiency but also such factors as legal restrictions on driving, road conditions, vehicle characteristics, and driver attributes. Using such a model would reduce any potential specification bias that a traffic fatalities model may have.

Prior research in this area has used a plethora of empirical techniques and a number of ways to define traffic fatalities. Unfortunately, little research has been conducted on the potential statistical differences between these various models, and what effect, if any, the use of different empirical techniques has on the results and thus the implications that policymakers may draw from this research. If different empirical techniques produce vastly different results, then research on traffic fatalities is of limited value unless robust results, or results that are similar between the different models, may be identified.

The present study has three primary purposes. First, this study will attempt to determine the effects of fuel efficiency standards on traffic fatalities. Second, this study will look at the effects of legal restrictions on traffic fatalities. Finally, the present study will compare and contrast three commonly used empirical techniques in order to determine which factors are the most robust or consistent in their effects on traffic fatalities.

The organization of the present study is as follows. This paper will first examine the prior literature in this area. Second, the empirical model employed in the present study will be discussed. Finally, the data used and the results obtained will be presented.

Results of the present study suggest that fuel efficiency standards have a negative effect on traffic fatalities, regardless of the type of empirical technique employed. These results indicate that, holding all other factors constant, the federal government's efforts to reduce gasoline consumption by increasing the fuel efficiency of cars did not result in an increase in deaths due to traffic accidents. Regarding other pertinent variables, the results of two of the three models suggest that socioeconomic factors, such as the age distribution of the state and per capita alcohol consumption, had much more significant effects on traffic fatalities than state-imposed legal restrictions, such as the minimum legal driving age.

LITERATURE REVIEW

The literature in the area of traffic fatalities and the causes of automobile accidents is extensive. Bester (2000) and Lourens, Visser, and Jessurun (1999) both offer excellent summaries of the current literature in this area. The present study's focus, however, is on the factors that affect traffic fatalities at the state-level, with special emphasis on the effects of fuel efficiency standards and legal restrictions on fatalities. Hence, the following literature review will focus on those articles that had as their primary focus the effect of fuel efficiency standards and other legal restrictions on traffic fatalities.

One of the earliest studies in this area was Loeb (1987). Using OLS and only looking at state-level data for the year 1979, Loeb concentrated his efforts on determining whether or not a vehicle inspection system at the state-level reduced traffic fatalities. The dependent variable, traffic fatalities, was defined as number of traffic fatalities per 100 million vehicle miles of travel. Loeb also included in his regression a variety of state-level socioeconomic variables, such as personal income per capita, population density, and the age distribution of the state's population. The author found that the minimum legal drinking age, income, and miles of highway at the state-level had no statistically-significant effects on traffic fatalities, while the population age distribution, per capita alcohol consumption, the average speed on interstate highways, and annual vehicle inspections were all statistically significant.

Using a sample of domestic sedans, Crandall and Graham (1989) estimated the weight of cars and found that, because of the government-imposed fuel efficiency standards (CAFE), cars weighed 18 percent less than they would have without the binding fuel constraints. Extrapolating their data to 1989, the authors contend that CAFE reduced the average car's weight by 500 pounds in 1989. Using prior research on weight-safety relationships, Crandall and Graham estimated that CAFE was associated with a 27 percent increase in occupant fatality risk.

Crandall and Graham estimated a traffic fatalities model using OLS and aggregate national data. The dependent variable was the ratio of fatalities to total motor vehicle miles traveled per year, which was the same as Loeb (1987). A few of the more pertinent explanatory variables used were per capita income, per capita alcohol consumption, and the average weight of cars on the road. Results indicated that income had a positive effect on traffic fatalities while vehicular weight had a negative effect.

Khazzoom (1994) examined the effect of vehicle weight and size on single-vehicle passenger car fatalities. In addition to estimating a model of CAFE, the author also estimated a traffic fatalities model. Using state-level data for the years 1985-1989, the author employed ridge estimation in order to account for potential problems with multicollinearity. He defined his dependent variable as total fatalities, and he used a log-log functional form. His results suggested that seat belt usage had an insignificant impact on traffic fatalities, while all of his other explanatory variables, which included the percentage of drivers older than 70, the percentage of drivers who drive while intoxicated, and per capita income, were significant with the expected sign.

Yun (2002) examined the role that CAFE had in creating or encouraging offsetting behaviors among drivers. The offsetting behavior hypothesis states that drivers are aware that the fuel economy standards have reduced the weights of cars and have thus increased the occupant fatality risk. In reaction to this increased risk, drivers operate their vehicles much more safely than they would have if CAFE had not been enacted. Estimating three equations where the dependent variable was measured as fatalities per 100 million vehicle miles and using national-level data for the period 1963-1993, Yun found that the fuel economy standards have caused a 21.1 percent decrease in the accident rate but a 14.99 percent increase in the vulnerability rate; hence, the net effect was a 6.11 percent decrease in the annual fatality rate. In addition, it was found that per capita expenditures on alcoholic beverages, the speed limit, and the percentage of very young and very old drivers all positively affected the fatality rate, while per capita income had a negative effect on traffic fatalities.

Noland (2004) used state-level data and incorporated into his analysis safety-belt usage laws in order to determine if CAFE had an effect on traffic fatalities. Noland used total fatalities as a dependent variable and employed a negative binomial model. His estimation of state-level fuel efficiency, however, does not take into account the various model years of cars that are present in any given state's stock of cars. Instead, he estimated fuel efficiency by dividing state-level fuel consumption by total vehicle miles traveled. This estimate is a proxy at best and does not take into account the potential model year mix of the cars on the road in any given year or state.

Using panel data estimation techniques, the author found that the fuel economy standards may have had an effect on traffic fatalities in the 1970s and early 1980s, but that since the mid-1980s, fuel economy standards have not had a statistically significant effect on traffic fatalities. Regarding his other explanatory variables, Noland found that per capita income, per capita alcohol consumption, and a greater share of drivers under the age of 25 all increased traffic fatalities.

Noland (2005) looked at international data regarding the effect of fuel economy standards on traffic fatalities. Using a methodology similar to his earlier work, the author once again used as his dependent variable total fatalities and employed a negative binomial model. Using data from thirteen countries for the years 1970-1996, the author found that fuel economy standards had no statistically-significant effect on traffic fatalities. Regarding the other independent variables in the total fatality regression, per capita alcohol consumption, motor vehicles per capita, vehicle miles traveled per capita all had positive and significant effects on fatalities. The percentage of population over 65 years of age and physicians per capita had negative effects on traffic fatalities.

In both of his studies, Noland noted that the use of count data and the negative binomial model were a vast improvement over the work of earlier studies, such as Khazzoom (1994) and Crandall and Graham (1989). He noted that both studies used techniques (OLS or time series estimation techniques) that are inappropriate when using count data (Noland, 2005, p.2186). Noland further noted that, although one may use a Poisson model for count data, using such a technique for traffic fatality data would be inappropriate given that the mean and variance of traffic fatality data typically are not equal. Hence, a fixed effects, negative binomial regression, which is a type of Poisson regression, was used instead.

What Noland failed to mention , however, was that neither Khazzoom (1994) nor Crandall and Graham (1989) actually used count data; rather, as noted above, they used fatality rate data which is not count data. Their primary reason for using least squares rather than the negative binomial model was because fatality rates can be assumed to be continuous; hence, the use of a Poisson-type regression in such a situation would actually be inappropriate.

One of the more recent studies on traffic fatalities was Vereeck and Vrolix (2007). Looking at data for 15 European countries and for the period 1996-2000, the authors attempted to determine if the willingness of citizens to obey traffic regulations had any effect on traffic fatalities. Defining their dependent variable as total fatalities, using a log-log functional form and panel data, Vereeck and Vrolix found that those nations that had citizens who were more likely to obey traffic laws had fewer traffic fatalities. Regarding the other explanatory variables used in their study, it was found that speed limits, vehicle miles traveled, and per capita alcohol consumption were all positively related to traffic fatalities, while GDP per capita was negatively related. It should be noted that the authors used at most five explanatory variables in order to estimate the determinants of traffic fatalities; this is rather low when compared to other studies in this area.

Finally, Vereeck and Vrolix noted that they used as a dependent variable the total number of fatalities and not a fatality rate, primarily because using a fatality rate would lead to spurious correlation (Vereeck and Vrolix, 2007, p.393). The authors made this comment assuming that traffic exposure, as measured by total vehicles miles traveled or vehicle miles traveled per capita, would be used as an explanatory variable. However, if a fatality rate is used as the dependent variable, then traffic exposure does need to be used as an explanatory variable since a rate does not necessarily depend upon traffic exposure as much as total fatalities do. The authors do not comment on the appropriateness of using a fatality rate model without an exposure variable. Finally, Vereeck and Vrolix do not reference Noland's 2004 or 2005 study at all and make no mention of the appropriateness of using a negative binomial model to estimate the determinants of total fatalities.

In summation, Loeb (1987), Crandall and Graham (1989), and Yun (2002) used OLS and fatalities per vehicle mile traveled as their dependent variables, while Khazzoom (1994), Noland (2004, 2005), and Vereeck and Vrolix (2007) used total fatalities as their dependent variables. However, three different estimating techniques were used by these researchers. Khazzoom used a ridge estimation model; Noland used a negative binomial model; and Vereeck and Vrolix used panel data estimation techniques.

Concerning possible statistical problems with their results, although several of the above studies used either time series data or panel data, none of them addressed the possibility of serial correlation; hence, as far as can be ascertained from the results presented, none tested for it, and none corrected for it. Regarding heteroskedasticity, most stated that either the use of logarithms or the use of panel data should mitigate its effects (Noland, 2005, p.2186). Finally, although several of the authors noted the possibility of multicollinearity, only Khazzoom believed that multicollinearity was a serious enough problem to address from a statistical standpoint; in order to correct this problem, he utilized the ridge estimation technique.

It is important to note that, in most of the prior research, little effort was made to develop a structural, individual-level model of vehicular safety. Most of the factors that affect highway safety are individual in nature; for example, people who drink and drive greatly reduce highway safety for not only themselves but also for their fellow travelers. Drinking and driving, however, is an individual-level decision, and no attempt was made in prior studies, nor is any made in the present study, to address the structural modeling of this individual-level decision. Instead, due to data limitations, most studies use aggregate state or national data to explain an individual-level phenomenon. Although this aggregate, reduced-form approach is less than ideal, it nonetheless is useful in providing indicators regarding the effectiveness of various public policy measures in reducing traffic fatalities.

EMPIRICAL TECHNIQUE

In examining the effects of traffic fatalities, one of the most important issues to be resolved is the way in which traffic fatalities, the dependent variable we are estimating, is defined. There are two general ways to do this: a fatality rate or a total fatality count. Fatality rates, however, can also be defined in several possible ways. The first fatality rate is the number of traffic fatalities per 100,000 population; this is a measure of the health risk associated with driving (Vereeck and Vrolix, 2007, p.386). A second way to define a fatality rate is to look at the traffic risk; the number of traffic fatalities per the total number of vehicles. Finally, the third way to define traffic fatalities is to look at the number of traffic fatalities per vehicle mile traveled. Vereek and Vrolix (2007) noted that this third measure is a much more accurate reflection of the true risk involved with driving. This third method will be the fatality rate employed in the present study.

In contrast to the use of fatality rates, however, one may use total fatalities as a dependent variable; this type of variable is a count variable since the total fatality data is a count of deaths due to traffic accidents. If one uses total fatalities, though, then one must take account of the total number of vehicle miles traveled.

In the present study, the fatality rate, as defined by fatalities per vehicle mile traveled, and total fatalities, the count variable, will be used as dependent variables. In order to estimate these dependent variables, three different empirical techniques will be examined: the first will be a fatality rate model using a least squares, fixed effects model; the second will be a total fatality model using a negative binomial, fixed effects model; and the third will be a total fatality model using a least squares, fixed effects model.

All three models will have almost all of the same explanatory variables; the only variable that will differ will be the exposure variable that was noted in Noland (2005) and Vereeck and Vrolix (2007). The reason for using almost all of the same explanatory variables is because one of the purposes of the present study is to compare the models to determine if the results obtained depend upon the type of model being used. Simply comparing the results of prior works would not achieve this since other researchers used a wide variety of explanatory variables in their traffic fatality models. The comparison of models in the present study should prove useful in determining the validity of the various empirical techniques, the veracity of the results obtained by prior researchers, and the robustness of any statistically-significant variables.

Regarding the common explanatory variables that will be used in all three empirical techniques, there are several different factors that may affect traffic fatalities. First, there are the regulatory constraints, the rules of the road (Peltzman, 1975). These include the following:

(1) speed limits (Vereeck and Vrolix, 2007; Ossiander and Cummings, 2002; Vernon, et al., 2003)
(2) mandatory seat belt laws (Cohen and Einav, 2001)
(3) minimum legal drinking ages (Vereeck and Vrolix, 2007; Bernhoft and Behrensdorff, 2003; Voas, et al., 2003; Sommers, 1985; Cook and Tauchen, 1984)
(4) minimum legal driving ages
(5) airbag requirement regulations.

Second, there are the roadway condition and vehicle characteristic variables:

(1) road maintenance (Noland and Oh, 2003)
(2) population density (Loeb, 1987)
(3) vehicles per capita (Noland, 2005)
(4) fuel efficiency (Noland, 2005; Noland, 2004; Khazzoom, 1994; Crandall and Graham, 1989).

Finally, there are personal characteristics of drivers in the state:

(1) age distribution (Noland, 2005; Noland, 2004; Yun, 2002; Khazzoom, 1994; Loeb, 1987)
(2) income (Noland, 2004; Yun, 2002; Khazzoom, 1994; Loeb, 1987)
(3) alcohol consumption (Vereeck and Vrolix, 2007; Noland, 2005; Noland, 2004; Voas, et al., 2003; Yun, 2002, Schechtman, et al., 1999).

Year is also included in order to capture linear trends in traffic fatalities not readily attributable to other factors. As noted, many of these explanatory variables have been used in prior studies. All variables used in the present study are defined in Table 1.

Given the above, the following three equations will be estimated in the present study:

$$\begin{aligned} FA = {} & a_0 + a_1 \ln AGE18 + a_2 \ln AGE25 + a_3 \ln AGE65 + a_4 \ln DENS + \\ & a_5 \ln SPEED + a_6 \ln DRINK + a_7 \ln DRIVE + a_8 \ln CAR + \\ & a_9 \ln TRUCK + a_{10} \ln VMT + a_{11}\, SEAT + a_{12} \ln INC + \\ & a_{13} \ln ALC + a_{14} \ln MAIN + a_{15}\, YEAR + a_{16} \ln MPG + a_{17}\, AIRBAG \end{aligned} \quad (1)$$

Table 1 Variable Definitions	
Variable	Definition
Fatalities (FA)	Total traffic fatalities
Fatalities per vehicle mile traveled (FR)	Ratio of total traffic fatalities to vehicle miles traveled
AGE18	Percentage of state population between the ages 18 to 24
AGE25	Percentage of state population between the ages 25 to 34
AGE65	Percentage of state population older than 65
DENS	Ratio of population to area
SPEED	Speed limit on rural, limited access, highways
DRINK	Minimum legal age to drink alcoholic beverages
DRIVE	Minimum legal age to operate motor vehicle
CAR	Ratio of number of passenger cars to population
TRUCK	Ratio of number of light trucks to population
VMT	Vehicle miles traveled per capita
SEAT	Equals one if state has mandatory seat belt law and zero otherwise
INC	Per capita annual income in real dollars
ALC	Per capita ethanol consumption in gallons
MAIN	Per capita expenditures on state highway and road maintenance
MPG	Ratio of vehicle miles traveled to gallons of gasoline consumed
AIRBAG	Equals one for years airbags were mandated for new vehicles (1987) and zero otherwise.

$$\begin{aligned} \ln FR = {} & a_1 \ln AGE18 + a_2 \ln AGE25 + a_3 \ln AGE65 + a_4 \ln DENS + \\ & a_5 \ln SPEED + a_6 \ln DRINK + a_7 \ln DRIVE + a_8 \ln CAR + \\ & a_9 \ln TRUCK + a_{10}\, SEAT + a_{11} \ln INC + a_{12} \ln ALC + \\ & a_{13} \ln MAIN + a_{14}\, YEAR + a_{15} \ln MPG + a_{16}\, AIRBAG \end{aligned} \quad (2)$$

$$\begin{aligned} \ln FA = {} & a_0 + a_1 \ln AGE18 + a_2 \ln AGE25 + a_3 \ln AGE65 + a_4 \ln DENS + \\ & a_5 \ln SPEED + a_6 \ln DRINK + a_7 \ln DRIVE + a_8 \ln CAR + \\ & a_9 \ln TRUCK + a_{10} \ln VMT + a_{11}\, SEAT + a_{12} \ln INC + \\ & a_{13} \ln ALC + a_{14} \ln MAIN + a_{15}\, YEAR + a_{16} \ln MPG + a_{17}\, AIRBAG \end{aligned} \quad (3)$$

Equation (1), the negative binomial regression, is similar to the work done by Noland (2004, 2005); equation (2), the least squares fatality rate model, is based on Loeb (1987), Crandall and Graham (1989), and Yun (2002); and equation (3), the least squares total fatalities model, is similar to Vereeck and Vrolix (2007).

As noted earlier, each equation uses the same explanatory variables except for the traffic exposure variable needed in the total fatality regressions (equations (1) and (3)). The exposure variable used in the present study is vehicle miles traveled per capita (Noland, 2005). All explanatory variables, where appropriate, are expressed in terms of natural logarithms. The use of logarithms should mitigate any potential problems associated with heteroskedasticity. In addition, the use of a log-log model means that the estimated coefficients may be interpreted as elasticities, although it is important to note that the equations being estimated in the present study are reduced-form equations, and not structural equations. Thus, although the coefficients will not be true elasticities, they may be interpreted as such given the functional form of the equations estimated.

DATA AND RESULTS

Data on seat belt laws, implementation of air bag regulations, maintenance expenditures, and traffic fatalities were all obtained from various agencies within the US Department of Transportation. Data on the minimum legal age to consume alcoholic beverages, the minimum legal age to operate a motor vehicle, and the state speed limit were obtained from *The Book of the States*. Data on income, population, age distributions, and alcohol consumption were obtained from the *Statistical Abstract of the United States*.

Data on state level fuel efficiency were calculated as follows: data on state-level consumption of gasoline for motor vehicle use was obtained from the Energy Information Administration. This value was then divided by vehicle miles traveled. Thus, an estimate of the fuel efficiency of all vehicles on the road was obtained. A version of this methodology was also employed by Noland (2005, 2004). Although this value is not the CAFE standard, it is a reasonable estimate of the fuel efficiency of all vehicles on the road in a given state for a particular year. If CAFE alone were used as an explanatory variable, then the fuel efficiencies of the new model cars sold in a particular year would be accounted for, while the fuel efficiencies of older model cars would be ignored. Hence, this measure of fuel efficiency would be biased upwards and would not be an accurate representation of the true average fuel efficiency of all vehicles on the road.

Regarding AIRBAG, the federal government mandated that over a three year period starting in 1987 all new cars would be equipped with air bags. Hence, by 1990, all new cars would have this equipment. Of course, many older vehicles that did not have air bags were still on the road. Over the years, however, the percentage of vehicles on the road that did not have air bags dropped significantly. Nonetheless, it should be noted that this variable is a somewhat less-than-accurate proxy of air bag implementation.

For the variable SPEED, it is important to note that, although many drivers do not obey their state's posted speed limits, it is assumed that if a state has a higher speed limit, then drivers in that state will drive faster than in a state with a lower posted speed limit. Hence, SPEED is considered to be a reasonable proxy for the average vehicular speed in a state.

All data is state level and is for the years 1978 through 2000. Due to incomplete data, Hawaii and Alaska were excluded from the analysis. All dollar values were deflated using the Consumer Price Index, base year 1982-1984. The panel data set employed in the present study thus covers 48 states and 23 years; the total number of observations is 1104.

Serial correlation was found to be a problem for equations (2) and (3). A first-order autoregressive process was assumed, and the results were corrected. Multicollinearity was not found to be a serious problem; a correlation matrix was estimated, and it was found that the correlations among regressors were low. In addition, further evidence that multicollinearity was not a problem was the fact that the R^2s for equations (2) and (3) were relatively high, and most of the explanatory variables were statistically significant.

Descriptive statistics are presented in Table 2. Results for equations (1), (2), and (3) are presented on Tables 3, 4, and 5, respectively. In addition, the results for all three regressions are compared on Table 6.

Table 2
Descriptive Statistics
N=1104

Variable	Mean	Minimum	Maximum
FA	899	63	5542
FR	0.0234	0.0078	0.06
AGE18	0.112	0.077	0.167
AGE25	0.163	0.108	0.246
AGE65	0.121	0.075	0.186
DENS	165.9	0.64	1137
SPEED	60.5	55	75
DRINK	20.6	18	21
DRIVE	17.4	15	21
CAR	0.52	0.307	0.79
TRUCK	0.205	0.03	0.674
VMT	8714	4169	16376
SEAT	0.505	0	1
INC	13319	8060	23636
ALC	2.47	1.2	6.69
MAIN	0.074	0.0096	0.48
MPG	18.1	10.82	25.5
AIRBAG	0.434	0	1

Table 3: Negative Binomial Results Model (Equation (1))			
Variable	Coefficient	Standard Error	Test Statistic
Constant	38.11	4.21	9.057***
AGE18	0.171	0.0414	4.123***
AGE25	-0.169	0.0458	-3.683***
AGE65	-0.0536	0.0499	-1.073
DENS	0.421	0.0317	13.263***
SPEED	0.078	0.056	1.398
DRINK	-0.106	0.047	-2.259**
DRIVE	-0.258	0.0617	-4.184***
CAR	-0.326	0.0388	-8.414***
TRUCK	0.00092	0.0166	0.056
VMT	0.799	0.045	17.767***
SEAT	0.0321	0.0094	3.433***
INC	0.165	0.0464	3.545***
ALC	0.599	0.041	14.636***
MAIN	-0.035	0.0149	-2.343**
YEAR	-0.0159	0.0024	-6.657***
MPG	-0.377	0.0619	-6.099***
AIRBAG	-0.0764	0.0148	-5.174***
Log-Likelihood = -5781.542 Significant at 1% Level = *** Significant at 5% Level = ** Significant at 10% Level = *			

Table 4: Fatality Rate Model (Equation (2))			
Variable	Coefficient	Standard Error	Test Statistic
AGE18	0.174	0.0518	3.357***
AGE25	-0.0638	0.0449	-1.420
AGE65	0.0367	0.0632	0.582
DENS	-0.0967	0.0518	-1.867*
SPEED	0.016	0.06	0.265
DRINK	-0.115	0.0959	-1.194
DRIVE	-0.246	0.156	-1.572
CAR	-0.09	0.051	-1.761*
TRUCK	-0.0106	0.0183	-0.583
SEAT	0.0192	0.0109	1.774*
INC	0.182	0.0572	3.181***
ALC	0.742	0.0607	12.212***
MAIN	-0.0412	0.0143	-2.867**
YEAR	-0.0182	0.0025	-7.213***
MPG	-0.542	0.0515	-10.529***
AIRBAG	-0.0378	0.0126	-3.008***
R^2 = 0.93 F = 221.36 Significant at 1% Level = *** Significant at 5% Level = ** Significant at 10% Level = *			

Table 5: Total Fatality Least Squares Model (Equation (3))			
Variable	Coefficient	Standard Error	Test Statistic
AGE18	0.194	0.0528	3.661***
AGE25	-0.0496	0.0455	-1.091
AGE65	0.0486	0.0634	0.766
DENS	0.861	0.0564	15.27***
SPEED	0.055	0.0637	0.862
DRINK	-0.111	0.0958	-1.164
DRIVE	-0.241	0.156	-1.544
CAR	-0.089	0.051	-1.743*
TRUCK	-0.0046	0.0186	-0.246
VMT	0.869	0.069	12.424***
SEAT	0.0213	0.0109	1.956*
INC	0.239	0.0647	3.688***
ALC	0.748	0.0607	12.312***
MAIN	-0.0394	0.0144	-2.739***
YEAR	-0.0183	0.0025	-7.287***
MPG	-0.474	0.063	-7.506***
AIRBAG	-0.0316	0.0129	-2.44**

R^2 = 0.99
F = 1797.03
Significant at 1% Level = ***
Significant at 5% Level = **
Significant at 10% Level = *

Table 6: Comparison of Models			
Variable	Negative Binomial	Fatality Rate	Total Fatality, Least Squares
AGE18	+	+	+
AGE25	-	?	?
AGE65	?	?	?
DENS	+	-	+
SPEED	?	?	?
DRINK	-	?	?
DRIVE	-	?	?
CAR	-	-	-
TRUCK	?	?	?
VMT	+	N/A	+
SEAT	+	+	+
INC	+	+	+
ALC	+	+	+
MAIN	-	-	-
YEAR	-	-	-
MPG	-	-	-
AIRBAG	-	-	-

Significant at 10% Level or Less and Positive: +
Significant at 10% Level or Less and Negative: -
Insignificant: ?

The results of all three models indicate that fuel efficiency has a statistically significant and negative effect on traffic fatalities at the state level; given that the results of all three models are the same, this result would be considered robust. This result runs counter to the results of most of the prior research. In addition, this result is important, since, given the recent dramatic increases in oil prices, any increase in fuel efficiency standards should not result in greater traffic fatalities.

Regarding the other explanatory variables, out of fifteen, excluding MPG, that were common to all three models, the following eight were significant with the same sign: AGE18, CAR, SEAT, INC, ALC, MAIN, YEAR, and AIRBAG. AGE18, SEAT, INC, and ALC were positive, while the others were negative; all of these results would be considered to be robust.

The model that had the most significant explanatory variables was the negative binomial regression (only three out of seventeen were insignificant). The model with the least number of variables significant was the least squares total fatalities model (six out of seventeen were insignificant). Only three variables were insignificant in all three models (AGE65, SPEED, and TRUCK). This comparison of the models suggests that most variables are robust, with the only inconsistencies being with the legal variables. Hence, use of any of the three most common empirical models should provide one with similar results, with the exception of the legal restrictions. Unfortunately, the effect of legal restrictions on traffic fatalities is a popular research topic, and few researchers utilize multiple models in order to determine if their results are robust.

As noted earlier, since a logarithmic or log-log model is used, the estimated coefficients for equations (2) and (3) may be interpreted as elasticities. Hence, regarding the result for MPG, for equation (2), the fatality rate model, a ten percent increase in fuel efficiency would reduce the fatality rate by 5.42 percent. For the total fatality model, a ten percent increase in fuel efficiency would reduce traffic fatalities by 4.74 percent. Although these elasticities are inelastic, they are nonetheless significant and suggest that increasing fuel efficiency would reduce traffic fatality by a significant amount. For example, at a fuel efficiency of 25 miles per gallon, an increase in this efficiency to only 27.5 would result in 263 fewer fatalities on average at the state level.

Regarding other factor elasticities, most are very small in magnitude. There are two explanatory variables, however, that have rather large elasticities. The first is ALC. A ten percent increase in per capita alcohol consumption would result in a 7.48 percent increase in total fatalities and a 7.42 percent increase in the fatality rate. Hence alcohol consumption has a statistically-significant and large effect on traffic fatalities, which is not unexpected. The second variable is VMT; for every ten percent increase in VMT, traffic fatalities increase by 8.69 percent. Since it is reasonable to assume that more auto accidents will occur if people drive more, this result is also not unexpected.

Most of the results of the present study are reasonable and consistent with prior research. These results suggest that road conditions, driver attributes, and vehicle characteristics are the most important determinants of traffic fatalities at the state level, irrespective of the type of empirical model used.

The one result not consistent with prior research was the positive sign on SEAT; this result suggests that the implementation of mandatory seat belt laws resulted in an increase in traffic fatalities. One possible reason for this result is that those individuals who most likely would wear seat belts were already using them; the law had no effect on their behavior. The results of the present study suggest that the mandatory seat belt laws may have been less than effective in convincing others to wear their seat belts.

Most importantly, however, several legal restrictions were insignificant in one or more of the models. SPEED, a measure of speed limits, was insignificant in all three models. The minimum legal drinking age and the minimum legal driving age were insignificant in two of the models. These results are consistent with the results of prior research. Vereeck and Vrolix (2007) found that most of the legal restrictions on driving that they examined were statistically insignificant; they noted that this confirmed their hypothesis that traffic laws could not explain the international differences in traffic fatalities. Apparently differences in laws cannot explain interstate differences in traffic fatalities either.

Conclusion

The purpose of the present study was to ascertain the determinants of state-level traffic fatalities and to compare the three most common models used in such research. Using data from 48 states over a 23 year time period, results of the present study suggested that fuel efficiency has a statistically significant and negative effect on traffic fatalities at the state level. This result, which is consistent across all three models and thus robust, runs counter to the results of most of the prior research. Holding all else constant, it appears that increases in the fuel efficiency of vehicles actually reduces traffic fatalities.

The results of the present study also suggest that road conditions, driver attributes, and vehicle characteristics are the most important determinants of traffic fatalities at the state level, irrespective of the type of empirical model used. Several legal restrictions were insignificant in one or more of the models. Thus, differences in laws cannot adequately explain the interstate differences in traffic fatalities. It appears that traffic fatalities are most affected by factors that policymakers have little control over, such as alcohol consumption and the percentage of drivers who are young; laws appear to have limited effects on driving behavior and ultimately the safety of driving on America's roads.

REFERENCES

Bernhoft, D.A. and Behrensdorff, I. (2003) "Effect of Lowering the Alcohol Limit in Denmark." *Accident Analysis and Prevention*, 35: 515-525.

Bester, J.B. (2000) "Explaining National Road Fatalities." *Accident Analysis and Prevention*, 32: 663-672.

Cohen, A. and Einav, L. (2001) *The Effect of Mandatory Seat Belt Laws on Driving Behavior And Traffic Fatalities*. (Olin Paper 341). Harvard Law School.

Cook, P. and Tauchen, G. (1984) "The Effect of Minimum Drinking Age Legislation on Youthful Auto Fatalities, 1970-1977." *The Journal of Legal Studies:* 169-190.

Crandall, R. and Graham, J. (1989). "The Effect of Fuel Economy Standards on Automobile Safety." *Journal of Law and Economics,* 32 (1): 97-118.

Khazzoom, J. David. (1994) "Fuel Efficiency and Automobile Safety: Single-Vehicle Highway Fatalities for Passenger Cars." *The Energy Journal,* 15 (4): 49-101.

Loeb, Peter. (1987) "The Determinants of Traffic Fatalities." *Journal of Transport Economics and Policy:* 279-287.

Lourens, P.F., Visser, J.A.M.M., and Jessurun, M. (1999). "Annual Mileage, Driving Violations and Accident Involvement in Relation to Driver's Sex, Age, and Level Of Education." *Accident Analysis and Prevention*, 31: 593-597.

Noland, R. (2004). "Motor Vehicle Fuel Efficiency and Traffic Fatalities." *The Energy Journal,* 25 (4): 1-22.

Noland, R. (2005). "Fuel Economy and Traffic Fatalities: Multivariate Analysis of International Data." *Energy Policy,* 33: 2183-2190.

Noland, R. and Oh, L. (2003) "The Effect of Infrastructure and Demographic Change on Traffic-Related Fatalities and Crashes: A Case Study of Illinois County-Level Data." *Accident Analysis and Prevention*, 36: 525-532.

Ossiander, E.M. and Cummings, P. (2002) "Freeway Speed Limits and Traffic Fatalities in Washington State." *Accident Analysis and Prevention*, 34: 13-18.

Peltzman, S. (1975) "The Effects of Automobile Safety Regulation." *Journal of Political Economy*, 83: 667-726.

Sommers, P. (1985) "Drinking Age and the 55 mph Speed Limit." *Atlantic Economic Journal*, 13: 43-48.

Vereeck, Lode and Klara Vrolix. (2007). "The Social Willingness to Comply with the Law: The Effect of Social Attitudes on Traffic Fatalities." *International Review Of Law and Economics,* 27: 385-408.

Vernon, D., Cook, L., Peterson, K., and Michael Dean, J. (2003) "Effect of Repeal of the National Maximum Speed Limit Law on Occurrence of Crashes, Injury Crashes, and Fatal Crashes on Utah Highways." *Accident Analysis and Prevention*, 35: 223-229.

Voas, R., Tippetts, A., and Fell, J. (2003) "Assessing the Effectiveness of Minimum Legal Drinking Age and Zero Tolerance Laws in the United States." *Accident Analysis and Prevention*, 35: 579-587.

Yun, J. (2002). "Offsetting Behavior Effects of the Corporate Average Fuel Economy Standards." *Economic Inquiry,* 40 (2): 260-270.