Effect of Fuel Economy on Automobile Safety

A Reexamination

Sanjana Ahmad and David L. Greene

Since 1975, the fuel economy of passenger cars and light trucks has been regulated by the corporate average fuel economy (CAFE) standards, established during the energy crises of the 1970s. Calls to increase fuel economy are usually met by a fierce debate on the effectiveness of the CAFE standards and their impact on highway safety. A seminal study of the link between CAFE and traffic fatalities was published by R. W. Crandall and J. D. Graham in 1989. They linked higher fuel economy levels to decreases in vehicle weight and correlated the decline in new car weight with about a 20% increase in occupant fatalities. The time series available to them, 1947–1981, includes only the first 4 years of fuel economy regulation, but any statistical relationship estimated over such a short period is questionable. This paper reexamines the relationship between U.S. light-duty vehicle fuel economy and highway fatalities from 1966 to 2002. Cointegration analysis reveals that the stationary linear relationships between the average fuel economy of passenger cars and light trucks and highway fatalities are negative: higher miles per gallon is significantly correlated with fewer fatalities. Log–log models are not stable and tend to produce statistically insignificant (negative) relationships between fuel economy and traffic fatalities. These results do not definitively establish a negative relationship between light-duty vehicle fuel economy and highway fatalities; instead they demonstrate that national aggregate statistics cannot support the assertion that increased fuel economy has led to increased traffic fatalities.

Since 1975, the fuel economy of passenger cars and light trucks has been regulated by the corporate average fuel economy (CAFE) standards established in the wake of the energy crises of the 1970s as part of the Energy Policy and Conservation Act of 1975. The program requires automobile producers to meet fleet average fuel economy standards set by the Department of Transportation. The fuel economy requirement for new cars was 18 miles per gallon (mpg) in 1978 and increased to 27.5 mpg in 1985. Regulations for new light trucks required a minimum efficiency of 17.5 mpg, increasing to 20.7 mpg by 1996. Failure to meet the standards incurs a penalty of $55 per mpg shortfall per car produced. Manufacturers have the ability to carry over exceedences or deficits in a movable 3-year forward–backward window.

Although the standards have not changed since the early 1990s, the overall fleet average fuel economy for new light-duty vehicles has gradually declined over the last decade due to increases in the average horsepower and weight of vehicles and an increase in the number of light trucks, which have much lower fuel economy than cars. Efforts to increase fuel economy have engendered a fierce debate on the effectiveness of the CAFE standards and their impact on highway safety. A 2002 study by the National Research Council found that the CAFE program clearly contributed to raising the fuel economy of the nation's light-duty vehicle fleet over the past 22 years. Yet, according to the study, the downweighting and downsizing that occurred in the 1970s and early 1980s may have caused 1,300 to 2,600 more traffic fatalities in 1993 than would have occurred without weight reductions and CAFE (*1*).

A seminal study of the link between CAFE and traffic accidents was published in 1989 by Crandall and Graham (*2*). Their analysis looked at passenger car weight versus traffic fatalities over the 35-year period from 1947 to 1981. They correlated higher fuel economy levels with decreases in vehicle weight and decreases in vehicle weight with higher traffic fatalities, concluding that CAFE was associated with about a 20% increase in highway fatalities. Note that the time series they used to correlate passenger car weight and highway fatalities includes only 4 years (1978–1981) during which the CAFE standards were in effect for new vehicles and additionally point out that it is the relationship between weight of the total vehicle stock and fatalities that is intended to be estimated. It appears likely that the time series on which Crandall and Graham based their estimates contained very little information on the relationship of interest.

The premises of this paper are that more can be learned by examining the entire period during which CAFE standards have been in effect and that, following Noland's (*3*) approach, one should examine the direct effect of fuel economy on traffic fatalities, implicitly including the intervening effect of weight but also allowing the possibility of other paths of influence. Like weight, engine size and power can be traded off for fuel economy and, in addition to other fuel-economy-related design changes such as the substitution of front-wheel for rear-wheel drive, might or might not have had safety implications. Opponents of government regulation of fuel economy often cite downweighting as the primary reason why CAFE standards should not be increased. A lightweight vehicle poses less risk to other road users, whereas a heavier vehicle provides less risk to its occupants. Some evidence exists that proportionally reducing the mass of all vehicles, or even just the heaviest cars and light trucks, could have a beneficial effect on safety (*1, 4*). On the other hand, increasing fuel economy does not necessarily require decreasing weight (*1*).

This paper briefly surveys the literature on modeling traffic fatalities, vehicle safety, and fuel economy. Then a national aggregate, time-series model of the correlation between traffic fatalities and

S. Ahmad, University of Tennessee, Knoxville, and D. L. Greene, Oak Ridge National Laboratory, National Transportation Research Center, 2360 Cherahala Boulevard, Knoxville, TN 37932.

Transportation Research Record: Journal of the Transportation Research Board, No. 1941, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 1–7.

motor vehicle fuel economy is estimated. The results provide no support for Crandall and Graham's early finding that increased fuel economy led to increased traffic fatalities.

LITERATURE REVIEW

The work of Crandall and Graham (referred to as CG) was the earliest effort to quantify the relationship between fatalities and fuel economy (*2*). Their study asserted that "much of the practical effect of CAFE in vehicle design has been upon the weight of automobiles," with technical design factors playing only a slightly more important role. Although this may have been true in the first few years after the oil crisis of 1973–1974, it has turned out to be incorrect in the long run. Model year 2003 cars and light trucks weigh 2.1% less than model year 1975 cars and light trucks, on average, but they get 58.8% better fuel economy (*5*). A weight reduction of 2.1%, by itself, could account for only a 1.5% increase in fuel economy (*1,* table 3-1). CG estimated the effects of CAFE on the average weight of new cars, the new car sales mix, and vehicle safety, using two submodels. For their weight (wt) submodel, they assumed that manufacturers' expectations of fuel prices (pgas), the price of steel (psteel), a size-class dummy variable (S_{ij}), and CAFE standards approximately 4 years in advance determine their vehicle production decisions. Using data for a sample of domestic sedans (195 total) from 1970 to 1985, they estimated the following equation:

$$\log \mathrm{wt}_{it} = a_0 + \sum_{j=1}^{4} a_j S_{ij} + a_5 \log \mathrm{pgas}_{t-4} + a_6 \log \mathrm{psteel}_{t-4} + a_7 \log \mathrm{CAFE} + u_{it} \tag{1}$$

where a_n are the coefficients of the regression and u is a stocastic error term.

On the basis of this model, CG concluded that vehicles were 360 to 470 lb lighter due to CAFE in the 1989 model year. They then substituted the predicted weight decrease into an equation estimated by Evans (*6*) using data on vehicle–vehicle crashes:

$$L(m) = \alpha e^{-0.00058m} \tag{2}$$

where

L = fatality risk associated with a reduction in mass, m;
a = the coefficient of the regression; and
e = numerical constant 2.718.

With this equation, CG calculated that CAFE was apparently responsible for a 14% to 28% increase in fatality risk.

To verify this result, CG estimated a national time-series model of highway fatalities. The explanatory variables included shares of truck and interstate miles in total vehicle miles traveled, personal income, alcohol consumption per capita, the number of young drivers, speed, weight (a variable predicted by their weight submodel), the price of a gallon of gasoline, a safety index, and a dummy variable for years in which the 55-mph speed limit was in effect. The results of this regression exhibited some statistical problems. The weight coefficient changed from statistically significant to insignificant over two variants of the occupant death rate model. Despite questions about the statistical validity of the effect of weight, CG estimated that the effect of CAFE (through the weight variable) was an increase in fatalities in the 14% to 28% range, verifying the numbers derived from Evans's equation.

CG's time series, 1947–1981, includes only the first 4 years in which the fuel economy regulations influenced the designs of new cars. Although the standards were known about 2 years before they became binding in 1978, over most of the time period of analysis, no fuel economy standards were in effect. In addition, because it takes about 15 years to replace the fleet of vehicles in use, by 1981 the CAFE standards could have had only a partial impact on the on-road vehicle fleet. Nevertheless, their work is frequently cited as evidence that higher fuel economy standards would lead to increases in fatalities (*7*).

Khazzoom also used a two-submodel approach (*8*). The first submodel predicts fleet fuel economy as a function of vehicle characteristics, demographic factors, and the CAFE standards. Using data from 17 manufacturers from 1978 to 1990, he found that fuel economy was affected most significantly by weight, horsepower, the gas-guzzler tax, the CAFE standards, car price, and income. Khazzoom also concluded that the adverse effect of horsepower on fatalities was twice that of weight, suggesting that trading off horsepower for fuel economy would be beneficial to safety.

Khazzoom's model regressed 1985 to 1989 state-level fatalities on the share of interstate miles driven by cars, personal income, percent of drunk drivers, total number of drivers and the percent over age 70, the ratio of 85th percentile speed to the 55-mph speed limit, curb weight, percent of drivers wearing seat belts, engine size, and car stability on total single-vehicle passenger car fatalities. Results indicated that an increased share of travel on interstate highways reduces traffic fatalities, while divergence from the speed limit and income have a positive, statistically significant impact on fatalities. Khazzoom found that downweighting is not likely to have a harmful effect with regard to single-vehicle crashes; he found that car dimensions and engine power have more important consequences.

In 1997, the National Highway Traffic Safety Administration (NHTSA) published a comprehensive study (*9*) of the relationship of vehicle mass to fatality risk for light trucks and cars from 1985 to 1993 in six different crash modes. The study explains that vehicle safety is affected by weight, rollover stability, directional stability, built-in occupant protection, and maneuverability, among other things. Confounding factors the NHTSA attempted to control for include annual mileage by age group, intrinsic vulnerability to fatal injury (which depends on age and sex), driving errors, driving intensity or aggressiveness, and geographic region. However, when analyzing the effects of vehicle weight on traffic fatalities, it is generally difficult to distinguish vehicle effects from driver behavior and environmental conditions. The driver is a major factor in more than 90% of all crashes, whereas environment and design are cited as major factors in about 30% and 10%, respectively (*10*). Using a logistic regression with a large number of individual observations of success or failure, the study estimated the impact of weight on the probability of fatality per induced exposure crash. Induced exposure crashes are those that result from no fault of the vehicle struck but only from its presence on the road. The regression corrected for a number of potentially confounding factors, including vehicle type, model year, all-wheel drive, and antilock braking system brakes. A 100-lb weight reduction in cars was predicted to increase fatalities by 1.1% over 1993 levels. The net effect of a 100-lb weight reduction for light trucks was 0.3% (about 40). A reduction in weight was estimated to increase injuries and fatalities for light-truck occupants but to make light trucks less damaging to other vehicles. The results also suggested that in crashes between vehicles of the same type, if both vehicles are lighter, overall fatalities would be reduced, but these relationships were not statistically significant (*10*). Other studies (*11, 12*) have predicted greater increases in fatalities for reductions in vehicle weight but do not correct nearly as rigorously for confounding factors as the NHTSA study did.

Van Auken and Zellner (*13*) analyzed 1985–1998 passenger car and 1985–1997 light-truck data using the NHTSA methodology. They found that a 100-lb weight reduction in the whole vehicle fleet would leave fatalities in 1999 unchanged. A follow-up study by the same authors in 2003 (*4*) looked at the effects of wheelbase and track width reduction in addition to weight. Their results indicated that reductions in weight decrease the overall number of fatalities, but corresponding changes in wheelbase and track width increase fatalities by a comparable amount. The overall, net effect was not statistically significant, implying that policies that induce reductions in weight without changing wheelbase or track width would reduce fatalities. These results are consistent with studies by Joksch et al. (*14*), who concluded that the increased weight of all cars is not necessarily good for highway safety.

In 2002, Greene and Keller published a "Dissent on Safety Issues" in a National Research Council Study of CAFE (*10*). They asserted that "the relationship between fuel economy and highway safety is complex, ambiguous, poorly understood, and not measurable by any known means at the present time." They agreed that occupants of the heavier vehicle in a vehicle-to-vehicle crash are safer than those in the lighter vehicle, yet they asserted that the impact of a decrease in the weight of all vehicles was uncertain (*10*). Using NHTSA's (*9*) weight fatality model, Greene and Keller calculated that a 10% reduction in the weight of all light-duty vehicles would result in a net increase of 16 fatalities in crashes involving more than one highway user, a statistically insignificant change. In single-vehicle crashes with fixed objects and rollovers, the NHTSA model predicted an increase of 830 fatalities. Greene and Keller (*10*) pointed out that no simple law of physics dictated such a result in single-vehicle crashes.

In 2003, NHTSA (*15,* p. xii) published an updated analysis that modified the methodology of the 1997 study, citing flaws in the calibration procedure of the 1997 study that led to "a systematic underestimate of the size-safety effect in every crash mode." The new analysis found that a 100-lb reduction in the weight and size of light trucks weighing 3,870 lb or more would not produce a statistically significant change in highway fatalities. However, for vehicles under 3,870 lb the same 100-lb decrease in size and weight would produce an estimated increase of 234 fatalities, with a confidence interval of 59 to 296. The 2003 study was careful to state key limitations of the analysis for predicting the impact of fleetwide weight reductions on traffic fatalities:

> The use of cross-sectional analysis for predictive purposes implicitly assumes that future weight reduction would be accompanied by reductions of track width, wheelbase, hood length, in the proportions that these parameters are related across the current fleet. (*15,* p. 79)
>
> Since most people can pick what car they drive, the observed size-safety effects could in part be due to intangible characteristics such as "driver quality" or "attitude," possibly confounded with the owners' choice of a small or large car. (*15,* p. 79)

The study presents a table indicating how apparently small changes in the data or model specification can lead to large changes in the predicted impacts of weight. Dropping two-door passenger cars from the database doubles the impact of weight on fixed-object collisions. Dropping police cars changes the signs of weight's effects in car-to-car crashes and crashes with pedestrians and cyclists. A correction for driver age magnifies the predicted effect of weight in all types of crashes and by more than a factor of 10 in the case of pedestrian–cyclist crashes (*15,* p. 172).

Noland (*3*) analyzed the effects of fuel economy on highway safety by using a time series of state level data from 1975 to 1998. Traffic fatalities from 1975 to 1998 and injury data from 1980 to 1997, as well as pedestrian fatalities and single- and multiple-vehicle crash data, are used as the dependent variables; the independent variables are total vehicle miles traveled, per capita income, total population, percent of population under 24 and over 65, percent seat belt usage (post-1990), seat belt law type (primary or secondary), and on-road fleet average fuel economy. Noland's results initially showed a positive relationship between fuel economy and fatalities but no significant effect on traffic injuries. Like other studies, Noland found that the coefficients of his models were not stable across model formulations. Unlike other studies, Noland explored the instabilities in detail. The addition (or omission) of per capita income, the percent of population between the ages of 15 and 24, and a seat belt variable all changed the coefficient for fuel economy. The relationship between fuel economy and traffic fatalities also turned out to be highly dependent on the choice of time series. From 1975 to 1984, increases in fuel economy had a statistically significant and positive effect on traffic fatalities. This relationship became negative between 1985 and 1992 and switched back again between 1993 and 1998. Overall, Noland found that a statistically significant positive correlation between fuel economy and traffic fatalities could be found only if the years 1975–1977 were included in the estimation. If these years were excluded, no statistically significant relationship could be found.

DATA AND METHODOLOGY

This study is based on national aggregate data for the years 1966–2002. The 37-year span includes 12 years before fuel economy regulation (pre-1978) and 25 years after. The dependent variable is total highway traffic fatalities, not the fatality rate per vehicle mile traveled. The use of a fatality rate implies an a priori assumption that the number of deaths increases in direct proportion to miles traveled, a highly dubious assumption (*16*). Table 1 presents the variables used in the analysis and the data sources. Fuel economy was calculated by dividing vehicle miles traveled by total fuel consumption by light-duty vehicles to obtain a yearly average for the fleet. Figure 1 plots both fatalities and fuel economy over time; both exhibit strong time trends. Fatalities appear to decrease with an interesting cycle, at least through 1992. The number of registered passenger cars and light trucks and their miles of travel are among the explanatory variables, as are driver demographics such as the number of drivers under the age of 24 and drivers 65 years of age and older. Also included are per capita alcohol consumption in gallons of ethanol consumed and a dummy variable representing the change in drinking laws. With the change in the voting age, most states also lowered the legal drinking age to 18 in 1970; the laws were later repealed after several studies showed that teenage drinking and driving had become a very serious problem (*17*).

The impact of seat belts is represented by the percent use of belts. NHTSA reports estimated national belt use since 1983, when 14% of drivers used seat belts. Usage before 1983 was linearly interpolated to zero in 1973. Federal law required front seat belts for all new cars in 1968, but the use of seat belts became prevalent in 1974 with the passage of interlock laws. The interlock laws required all vehicles to have a system that prevented the engine from starting unless driver and passengers were buckled up. Before this time, belt use was essentially zero. Speed limit laws have also been shown to affect fatalities (*18*). Two dummy variables, measuring the impact of changes in speed limit laws, are included. The federal law enacting a 55-mph speed limit on all interstate highways was passed in 1974; this was changed in 1987 to allow for 55 mph in urban areas

TABLE 1 Variables

Variable	Units	Source (and Necessary Transformations)
Fatalities	Total deaths	Table FI-10 (*19*): "US Total"
VMT	1000s miles	Table VM-1 (*19*): "Total Rural and Urban" for "All Motor Vehicles"
Population	1000 people	(*20*)
GDP	Billion 2000$	National Income and Product Accounts tables Table 1.1.6 (*21*): Real Gross Domestic Product, Chained Dollars
Fuel price	Chained 1996$	Annual Energy Review (2002) Table 5.22 (*22*) 1966–75: Leaded Regular-Real; 1976–77: Unleaded Regular-Real; 1977–present: All Grades-Real
Fuel economy	Miles per gallon	Table VM-1 (*19*): "Fuel Consumed" and "Total Urban and Rural Miles" for "Passenger Cars and Other 2-Axle 4-Tire Vehicles" (representative of Light Duty Vehicle Fleet); MPG is total vehicle miles divided by total fuel consumption
Drivers	1000 people	Table DL-20 (*19*): 24 and Under, 65 and over
Registered vehicles	1000 people	Table VM-1 (*19*): "Passenger cars" Representative of Cars and "Other 2-Axle 4-Tire Vehicles 2" for Light Trucks
Alcohol consumption	Gal of ethanol consumed, per population age 15 and up	(*23*)
Seat belts	Weighted national use rate	NHTSA (*18*): 1983 to 1988 from 19-city surveys, 1988–1999 state surveys, 2000–2002 NOPUS, Pre-1982: linear extrapolation from 1973 (zero point) to 1984
Dummy variables	1 for the years indicated below and 0 otherwise	
1974	1 in 1974 for the oil embargo.	
Speed limit 1975–86	1 during 1975–1986 to capture the effects of the 55 mph speed limit on Interstate highways.	
Speed limit 1987–1995	1 during the years 1987–1995, where speed limit laws allowed for 55 mph in urban areas and 65 mph in rural areas. (In 1996, regulation on urban areas was dropped.)	
Alcohol law	1 from 1970–1975 when the majority of states also lowered the legal drinking age to 18.	

VMT = vehicle miles traveled.

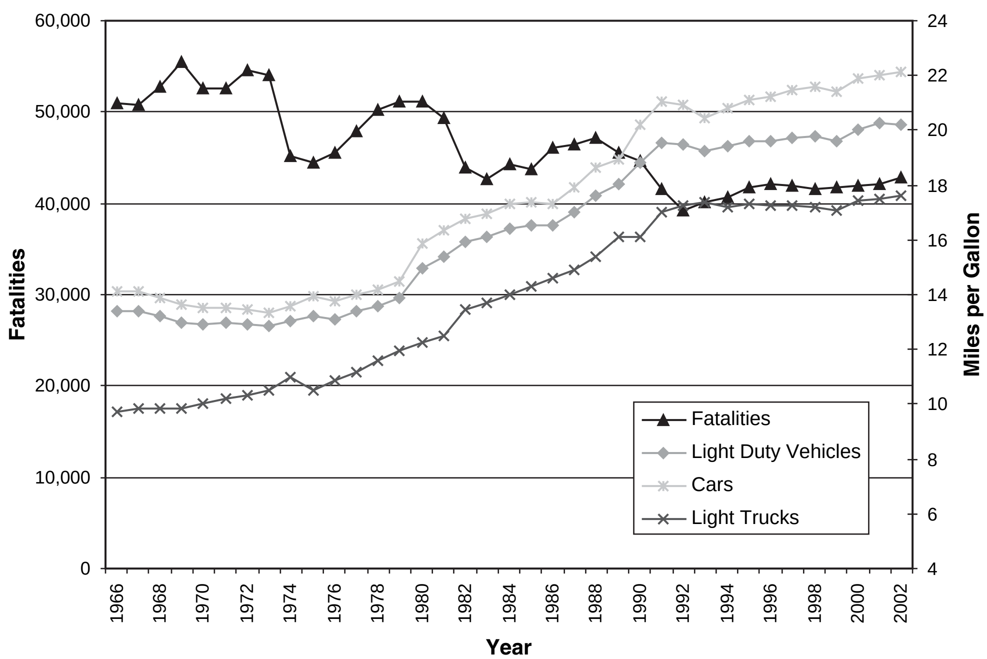

FIGURE 1 Motor vehicle fuel economy and traffic fatalities, 1966–2002.

and 65 mph in rural areas. In 1996, the federal 55-mph limit in urban areas was dropped as well. The first variable measures the impact of the beginning of regulation in 1974 until laws were changed in 1987, and the second variable examines the 55–65 split between urban and rural interstate highways from 1987 to 1996. Economic factors are represented by gross domestic product (GDP) and the average price of a gallon of unleaded gasoline. A dummy variable measuring the impact of the oil embargo of 1974 was also included. The embargo changed driving patterns significantly because of a shortage of gasoline.

Thus, the final model formulation is the following, where f is a linear function of the right-hand–side variables:

$$\text{fatalities} = f(\text{total miles traveled by light-duty vehicles, total population, chained GDP, average price of a gallon of gas, light-duty fleet fuel economy, drivers under 24, drivers over 65, per capita alcohol consumption, drinking age at 18, 1974 speed limit legislation, 1987 speed limit legislation, number of registered cars and light trucks, percent of drivers wearing a seat belt})$$

Several of these variables are highly correlated, including vehicle miles traveled, GDP, population, and the number of light trucks. Regressions were estimated with and without a linear time trend variable.

To estimate a stable long-term relationship between fatalities and the independent variables, the linear relationship between them must be cointegrated of Order 0 (*24*). If the dependent and independent variables are nonstationary of Order 1, as they are here, the regression model $y_t - B \times X_t$ must be cointegrated of Order 0 (*24*). If the model is not cointegrated with Order 0, there is no stable long-run relationship between the dependent and independent variables and the regression values are spurious. The Dickey–Fuller unit root test was used to test for stationarity of the variables and residuals (*25*). All variables are nonstationary Order 1 with stochastic trends, except population, cars, and light trucks, which are nonstationary (Order 1) with deterministic trends.

For count data, it is generally more appropriate to use a Poisson or negative binomial regression, as Noland did in his analysis (*3*). However, Poisson distributions converge to the normal distribution as the number of counts increases. With at least 40,000 fatalities per year, the normal distribution should be closely approximated by these data. The Jarque–Bera test for normality of the residuals was used to verify that assumption.

All models were also tested for autocorrelation and heteroskedasticity. All statistical analysis was carried out with RATS analysis software (*27*).

RESULTS

Two functional forms were tested in this study: linear and logarithmic. The residuals for each model were tested for stability, normality, and heteroskedasticity. The coefficient estimates, t-values, R^2 values, Durbin–Watson statistic, and residual tests are presented in Tables 2 and 3.

In the linear regressions, only light-duty fuel economy, the real price of a gallon of unleaded gasoline, and the 1974 speed limit law were statistically significant in all model formulations. In contradiction to CG's findings, fuel economy had a statistically significant negative impact on fatalities. Lowering the speed limit to 55 mph was also negatively correlated with fatalities, whereas an increase in the price of gas had a positive effect. The hypothesis that the residuals are normally distributed was not rejected, nor was the hypothesis of stationarity of the residuals or the test for homoskedasticity; the test for autocorrelation was inconclusive. Thus, the linear model satisfies the requirements for cointegration and all other tests with the possible exception of autocorrelation of the residuals. Introducing a linear time trend has little effect on the coefficient estimates or other properties of the model.

The fact that the Durbin–Watson statistics for the linear model are inconclusive led to the testing of models with a first-order autocorrelation correction [AR(1)] (using the Hildreth–Lu procedure). With AR(1) correction, only the 55-mph speed variable is statistically significant. However, the estimated autocorrelation coefficient is not significantly different from 1.0, suggesting that the AR(1) model may be reflecting short-run instead of long-run relationships. When a trend variable is included in the AR(1) model the estimated correlation coefficient is again not significantly different from 1.0. The latter model is the only one in which fuel economy appears with a positive coefficient, but the coefficient is not close to being statistically significant ($t = 0.2$, $\alpha = 0.8$).

Using the three statistically significant variables from the basic linear model, a smaller model was estimated. The regression yielded similar results, although it failed the Durbin–Watson test and showed statistically significant heteroskedasticity. The AR(1) Hildreth–Lu procedure was used to correct for autocorrelation; results are presented in Table 3. Fuel price drops out as statistically insignificant, and the model is borderline with respect to heteroskedasticity of residuals ($\alpha = 0.07$). A Chow-test was used to analyze the stability of the coefficient estimates over time. On the basis of Noland's finding that the sign of the coefficient of fuel economy changed in 1983 the sample was split into two parts: pre-1983 and 1983–2002. The hypothesis of parameter equality for the two time periods was not rejected.

One possible way to correct the problem of heteroskedasticity is to estimate a log–log model. The residuals of the log–log model passed tests for normality, stationarity, and homoskedasticity but the Durbin–Watson test was again inconclusive. Furthermore, fuel economy was the only statistically significant variable at the $\alpha = 0.05$ level; GDP and the constant were significant at the 6% level. When an AR(1) procedure was applied to correct for autocorrelation, all variables in the log–log model became insignificant. A more parsimonious log–log model, including only GDP and mpg, showed serious problems with autocorrelation and had nonstationary residuals. The AR(1) version of the parsimonious log–log model had a ρ value of 1.0, indicating that the variables should be differenced. In the differenced model, fuel economy was nonsignificant, and errors were heteroskedastic and not normally distributed. These serious deficiencies suggest that the log–log form is not appropriate for these data.

CONCLUSION

This paper has reexamined the relationship between light-duty vehicle fuel economy and highway fatalities from 1966 to 2002. Whereas the seminal study by CG concluded that increases in fuel economy led to more traffic-related deaths, this study finds no support for that hypothesis in national time-series data. A recent study by Noland (*3*)

TABLE 2 Linear Regression Results

Model #	Without Time Trend		With Time Trend		Without Trend AR(1) Corrected		With Trend AR(1) Corrected	
	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat
Constant	*159,003*	*2.34*	–59,168	–.035	148,238	2.06	–167,582	–1.10
VMT	4.88	0.25	27.7	1.41	–6.52	–0.28	6.15	0.25
POP	–0.363	–1.12	0.678	0.86	–0.527	–1.26	0.776	1.10
GDP	2.55	0.66	–0.474	–0.11	7.51	1.40	10.35	2.04
Price of gas	*6,952*	*2.33*	*7,134*	*2.45*	3,603	1.00	3,463	1.02
MPG	*–3,642*	*–2.98*	*–3,212*	*–2.61*	–2,066	–1.16	401	0.22
1974	–2,405	–1.13	–2,792	–1.33	–2,482	–1.34	–3,465	–2.20
Speed 1	*–7,192*	*–3.63*	*–5,390*	*–2.34*	*–5,271*	*–2.5*	*–2,571*	*–1.28*
Speed 2	–3,104	–1.69	–2,260	–1.20	–2,883	–1.57	–1,696	–1.04
Drivers < 24	–136,578	–0.95	–294,507	–1.66	20,950	0.12	–24,025	–0.16
Drivers > 65	–15,039	–0.07	–84,968	–0.44	42,738	0.24	50,364	0.35
Alcohol	4,885	0.43	14,073	1.10	–2,795	–0.22	–2,803	–0.27
Drinking age	–588	–0.40	–62.1	–0.04	–815	–0.56	–1,001	–0.77
% seat belts	14,704	0.97	20,297	1.33	17,876	1.19	*29,865*	*2.13*
Cars	0.143	0.90	0.332	1.64	0.169	1.07	*0.502*	*2.65*
Light trucks	–0.098	0.28	–0.267	–0.75	–0.14	–0.40	–0.228	–0.70
Linear trend			–3,671	–1.44			*–5,947*	*–2.46*
R^2	0.931		0.937		0.933		0.949	
Adj R^2	0.882		0.888		0.877		0.901	
D–W stat[a]	1.72		1.680		1.67		1.42	
Rho					0.510	1.44	0.708	3.95
DF unit root[b]	–5.15		–4.99		–5.17		–4.50	
Jarque–Bera[c]	0.125 (0.939)		0.119 (0.941)		0.961 (0.618)		1.517 (0.468)	
Breusch–Pagan[c]	14.60 (0.481)		16.58 (0.413)		10.69 (0.774)		12.24 (0.728)	

[a]Critical values for this test at the 5% level are approximately lower bound = 0.60 and upper bound = 2.47. H_0: no autocorrelation.
[b]Critical values for this test are 1% = –3.617, 5% = –2.942, 10% = –2.609. H_0: residuals are nonstationary of Order 1.
[c]Significance level in parentheses. Jarque–Bera H_0: residuals are normally distributed. Breusch–Pagan H_0: residuals are homoskedastic.
VMT = vehicle miles traveled; POP = population; GDP = gross domestic product; MPG = miles per gallon; D–W stat = Durbin–Watson statistic; DF = Dickey–Fuller.
NOTE: Numbers in italics are the coefficients that are statistically different from zero.

TABLE 3 Linear Regression Results: Parsimonious Model

Model #	Without Time Trend		With Time Trend		Without Trend AR(1) Corrected		With Trend AR(1) Corrected	
	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat	Coefficient	*T*-Stat
Constant	69,573	23.78	78,331	12.81	73,186	14.99	82,745	8.16
Price of gas	4,635	2.52	5,630	2.96	2,048	0.97	2,875	1.33
MPG	–1,703	–12.84	–2,521	–4.83	–1,710	–6.85	–2,651	–2.97
Speed 1	–5,388	–5.00	–6,514	–5.17	–4,789	–3.61	–5,307	–3.83
Linear trend			203	1.62			262	1.09
R^2	0.833		0.846		0.872		0.877	
Adj R^2	0.818		0.827		0.856		0.857	
D–W stat[a]	1.04		1.15		1.65		1.74	
Rho					0.557	3.24	0.523	2.82
DF unit root[b]	–3.43		–3.73		–4.96		–5.14	
Jarque–Bera[c]	0.064 (0.968)		0.776 (0.678)		0.451 (0.798)		0.090 (0.955)	
Breusch–Pagan[c]	12.44 (0.006)		15.94 (0.003)		7.06 (0.070)		10.19 (0.037)	

[a]Critical values for this test at the 5% level are approximately lower bound = 1.34 and upper bound = 1.60. H_0: no autocorrelation.
[b]Critical values for this test are 1% = –3.617, 5% = –2.942, 10% = –2.609. H_0: residuals are nonstationary of Order 1.
[c]Significance level in parentheses. Jarque–Bera H_0: residuals are normally distributed. Breusch–Pagan H_0: residuals are homoskedastic.
MPG = miles per gallon; D–W stat = Durbin–Watson statistic; DF = Dickey–Fuller.

suggested that the relationship between fuel economy and traffic accidents at the state level was highly dependent on choice of time series. This analysis, based on national level data, reveals that light-duty fuel economy increases are either negatively correlated with traffic fatalities or insignificant.

These results, as well as those of Noland, contradict the earlier findings of CG (*2*), which were based on very limited experience with fuel economy standards. Although these results do not conclusively demonstrate that increasing fuel economy would be beneficial to traffic safety, it is clear that aggregate fatality statistics do not support a positive correlation between fuel economy and fatalities.

REFERENCES

1. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* National Research Council, National Academy Press, Washington, D.C., 2002.
2. Crandall, R. W., and J. D. Graham. The Effect of Fuel Economy Standards on Automobile Safety. *Journal of Law and Economics,* Vol. 32, 1989, pp. 97–118.
3. Noland, R. B. Motor Vehicle Fuel Efficiency and Traffic Fatalities. *Energy Journal,* Vol. 25, No. 4, pp. 1–22.
4. Van Auken, R. M., and J. W. Zellner. *A Further Assessment of the Effects of Vehicle Weight and Size Parameters on Fatality Risk in Model Year 1985–1998 Passenger Cars and 1985–1997 Light Trucks.* Publication DRI-TR-03-01. Dynamic Research, Inc., Torrance, Calif., 2003.
5. Hellman, K. H., and R. M. Heavenrich. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003.* EPA420-R-03-006, Environmental Protection Agency, Washington, D.C., April 2003.
6. Evans, L. *Car Mass and Likelihood of Occupant Fatality.* SAE Technical Paper Series 820807, Society of Automotive Engineers, Warrendale, Pa., 1982.
7. Defalco, J. *The Deadly Effects of Fuel Economy Standards: CAFE's Lethal Impact on Auto Safety.* Competitive Enterprise Institute, Washington, D.C., 2002.
8. Khazzoom, D. J. Fuel Efficiency and Automobile Safety: Single-Vehicle Highway Fatalities for Passenger Cars. *Energy Journal,* Vol. 15, No. 4, 1994, pp. 49–101.
9. Kahane, C. *Relationships Between Vehicle Size and Fatality Risk in Model Year 1985–93 Passenger Cars and Light Trucks.* Publication DOT HS 808 570. National Highway Traffic Safety Administration, U.S. Department of Transportation, 1997.
10. Greene, D., and M. Keller. Dissent on Safety Issues: Fuel Economy and Highway Safety. In *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* TRB, National Research Council, Washington, D.C., 2002, pp. 117–124.
11. Lund, A. K., B. O'Neill, J. M. Nolan, and J. F. Chapline. *Crash Compatibility Issue in Perspective.* SAE Technical Paper Series 2000-01-13778, Society of Automotive Engineers, Warrendale, Pa., 2000.
12. Partyka, S. C. *Registration-Based Fatality Rates by Car Size from 1978 Through 1987, Paper on Car Size—Safety and Trends.* Publication DOT HS 807 44. National Highway Traffic Safety Administration, U.S. Department of Transportation, 1995.
13. Van Auken, R. M., and J. W. Zellner. *An Assessment of the Effects of Vehicle Weight on Fatality Risk in Model Year 1985–1998 Passenger Cars and 1985–1997 Light Trucks.* Publication DRI-TR-02-02. Dynamic Research, Inc., Torrance, Calif., 2002.
14. Joksch, H., D. Massie, and R. Pichler. *Vehicle Aggressivity: Fleet Characterization Using Traffic Collision Data.* Publication DOT HS 808 679. National Highway Traffic Safety Administration, U.S. Department of Transportation, 1994.
15. Kahane, C. J. *Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991–1999 Passenger Cars and Light Trucks.* DOT HS 809 662. National Highway Traffic Safety Administration, U.S. Department of Transportation, Oct. 2003.
16. Joksch, H. C. Critique of Sam Peltzman's Study: The Effects of Automobile Safety Regulation. *Accident Analysis and Prevention,* Vol. 8, 1976, pp. 129–137.
17. Hammond, R. Legal Drinking Age at 18 or 21—Does It Make a Difference? *Journal of Alcohol and Drug Education,* Vol. 18, 1973, pp. 9–13.
18. *Special Report 278: Buckling Up: Technologies to Increase Seat Belt Use.* Transportation Research Board of the National Academies, Washington, D.C., 2004.
19. FHWA. Office of Highway Information Management. *1995–2002 Highway Statistics.* http://www.fhwa.dot.gov/policy/ohim/hs02/index.htm. Accessed February 16, 2004.
20. U.S. Census Bureau. *Statistical Abstract of the United States, 2003.* http://www.census.gov/statab/hist/HS-01.pdf.
21. U.S. Department of Commerce. Bureau of Economic Accounts. http://www.bea.gov/bea/dn/nipaweb/SelectTable.asp?Selected=N. Accessed December 16, 2003.
22. Energy Information Administration. *Annual Energy Review 2002.* Publication DOE/EIA-0384 (2002). U.S. Department of Energy, Office of Energy Markets and End Use, 2003.
23. National Institutes of Health. National Institute on Alcohol Abuse and Alcoholism. *Apparent per Capita Ethanol Consumption for the United States, 1850–2000.* http://www.niaaa.nih.gov/Resources/DatabaseResources/QuickFacts/AlcoholSales/consumol.htm. Accessed December 16, 2003.
24. Glassbrenner, D. *Safety Belt and Helmet Use in 2002—Overall Results.* Publication DOT HS 809 500. National Highway Traffic Safety Administration, U.S. Department of Transportation, 2002.
25. Maddala, G. S., and I. M. Kim. *Unit Roots, Cointegration and Structural Change.* Cambridge University Press, Cambridge, United Kingdom, 2003.
26. Maddala, G. S. *Introduction to Econometrics.* John Wiley & Sons, New York, 2001.
27. *RATS Version 6 User's Guide.* Estima, Evanston, Ill., 2004.

The Transportation Energy Committee sponsored publication of this paper.