OFFSETTING BEHAVIOR EFFECTS OF THE CORPORATE AVERAGE FUEL ECONOMY STANDARDS

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Research has concluded that regulatory attempts to improve fuel economy, such as the Corporate Average Fuel Economy (CAFE) Standards, lower the average weight of an automobile. Ceteris paribus, *this reduction in weight is detrimental to the overall level of vehicle safety. However, this study attempts to explicitly measure possible behavioral responses on the part of drivers that could offset some of the loss in safety. The results indicate that CAFE, although increasing the vulnerability rate by approximately 20%, has* reduced *the accident rate by 26%. The net effect on the fatality rate is a decrease of approximately 6%.* (*JEL* D81, L51, L62)

I. INTRODUCTION

Consumers value many attributes of an automobile. The problem for regulators is that many features are highly interrelated, such as safety and fuel economy improvements. Both features are highly correlated with vehicle weight. Greater weight increases the level of safety, in terms of crashworthiness, but decreases the fuel economy. Therefore, regulatory attempts to improve fuel economy, such as the Corporate Average Fuel Economy (CAFE) Standards,[1] are likely to alter average vehicle weight, which will alter the safety of a vehicle. Crandall and Graham (1989) find the reduction in weight attributable to CAFE results in a 14%–28% increase in occupant fatality risk.

This article seeks to determine whether drivers are changing their behavior to mitigate the detrimental safety effects of CAFE, which is essentially another application of Peltzman's (1975) offsetting behavior hypothesis. CAFE, through a reduction in passenger car weight, will increase the ex ante cost of risky driving[2] relative to its expected benefit. The reason is that, once an accident occurs, the probability of serious injury or death has increased. The offsetting behavior hypothesis is that consumers, aware of the increased vulnerability, will exercise greater due care and reduce the amount of risky driving on the road as a result of CAFE.

However, CAFE has not just affected the average passenger car weight. Godek (1997) and Yun (1999) indicate that CAFE has positively affected the relative sales of light trucks[3] to passenger cars. If we assume that light trucks are basically heavy cars with

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1. CAFE is part of the larger Energy Policy and Conservation Act, which was passed in 1975. (Title 15 U.S.C.A. §2001–§2011, Title 49 U.S.C.A. §32901–§32919.)

2. This is a broad term that includes speeding, driving with less care, driving in bad weather, not wearing a seat belt, and so forth.

3. Light trucks, as defined for CAFE, are minivans, pickup trucks, and sport-utility vehicles (SUVs) with a gross-vehicle-weight (GVW) rating under 8500 lbs.

ABBREVIATIONS

CAFE: Corporate Average Fuel Economy
CPI: Consumer Price Index
GAO: General Accounting Office
GDP: Gross Domestic Product
GVW: Gross Vehicle Weight
NHTSA: National Highway Traffic Safety Administration
OLS: Ordinary Least Squares
SUV: Sport Utility Vehicle

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greater visibility, the same arguments made for offsetting behavior on the part of passenger car drivers can be applied here.[4] The main difference is that truck drivers will be more aggressive and risky because trucks are heavier, which lowers the cost of risky driving. Thus, if CAFE induces more trucks to be on the road, according to the offsetting behavior hypothesis, CAFE will increase the amount of aggressive truck driving while simultaneously decreasing the amount of aggressive car driving. Although the article will focus on the offsetting behavior from changes in passenger car weight, it is just as relevant for changes in relative truck miles driven.

Section II reviews the recent research linking automobile weight changes with CAFE and recent empirical studies that apply offsetting behavior to automobile regulations.[5] Section III details the methodology used to test the offsetting behavior hypothesis. Section IV contains a discussion of the data. The results are reported in section V, and section VI concludes the article.

II. BACKGROUND

The CAFE standards were initially set at 18.0 mpg for passenger cars and between 15.8 to 17.2 mpg for various light trucks. These standards have steadily increased to the current levels of 27.5 mpg for passenger cars and 20.7 mpg for light trucks.[6]

The key impact of CAFE on consumer safety is a reduction in the average passenger car weight. Figure 1 illustrates the fall in weight since CAFE's passage in 1975. Crandall and Graham (1989) attribute 14% of the fall in weight to CAFE.[7] Using single-car accident data, they estimate the elasticity of highway occupant fatality rates with respect to average car weight is between −1.22 and −2.30, which implies a 17%–32.2% increase in the fatality rate due to CAFE. Using the upper and lower bounds, Crandall and Graham (1989) estimate that CAFE is responsible for 2,200–3,900 more deaths over the life span of the cars from a given model year.[8] However, there is no attempt to explicitly measure possible offsetting behavior effects.

Not all studies find a positive relationship between weight and safety. The General Accounting Office (GAO) (1991) acknowledges a theoretical link between automobile size and safety; however, they find no direct empirical link between the two. They find the highest fatality rates occur not in the lightest cars but in middle-weight cars. The reasoning is that larger, heavier cars increase the probability of a fatality for the lighter automobile passengers, as well as subjecting their own occupants to greater force (i.e., mass times acceleration) at impact. Lighter vehicles, though generally less stable and crashworthy, create less force. The GAO study indicates that there is no simple relationship between vehicle weight and fatalities. Their explanation relies on force and weight variance, which does not account for the possibility that drivers are changing their behavior.

The concept of offsetting behavior, as applied to automobile safety changes, was initially suggested in Lave and Weber (1970); however, Peltzman (1975) formalized it, both theoretically and empirically, and spurred much of the research on the subject. Looking at the National Highway Traffic Safety Administration's (NHTSA) broad safety standards implemented in 1966, he concludes that these standards had no affect on the highway death rate. The most plausible explanation, in Peltzman's estimation, is that safety regulations do reduce the probability of death *given an accident*, but drivers offset this gain with more risky driving, thus altering the frequency of accidents. Crandall et al. (1986),

4. This is obviously a simplification of the safety of light trucks. Light trucks create negative visibility externalities (e.g., a car immediately behind an SUV cannot see beyond the vehicle). Light trucks, with a higher center of gravity, have a greater propensity to become upended or roll over. Therefore, a priori, one cannot really determine whether a light truck is safer than a passenger car because there are competing effects. However, it would seem that weight should be weighed heavily in determining whether one type of vehicle is safer than another.

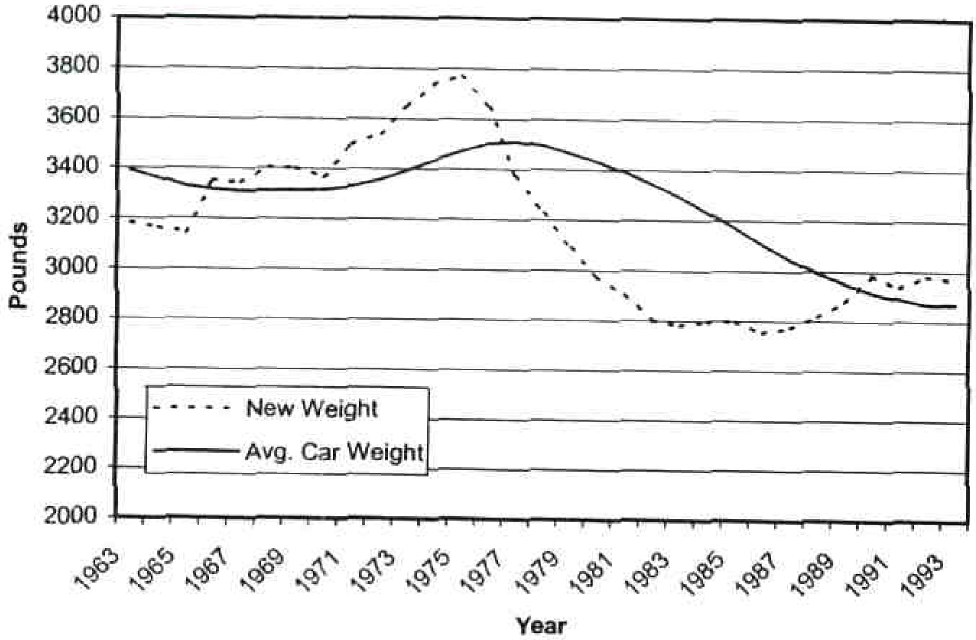
5. A theoretical model of offsetting behavior is omitted due to the prior treatment on the subject by Peltzman (1975) and Chirinko and Harper (1993).

6. The standards apply equally to all auto producers with U.S. sales over 10,000 autos per model year. As long as a firm's total fleet average mpg is above the CAFE standard for that year, there is no violation. Failure to meet the standards results in a civil penalty equal to [$50 × (CAFE standard − firm's fleet average) × total number of vehicles sold].

7. Moore (1990) and Laffer (1991) support their findings.

8. DeFalco (1997) updates their estimates for 1996: 2700–4700 deaths attributable to CAFE.

FIGURE 1
Passenger Car Weights



Source: Author's calculations based on data from *Ward's Automotive Yearbook* and *AAMA Motor Vehicles Facts & Figures*.

although critical of some of Peltzman's econometric assumptions, also find that offsetting behavior cannot be dismissed in evaluating the effectiveness of safety regulations.

Recent studies continue to show the relevance of the offsetting behavior hypothesis for automobile safety regulations. Chirinko and Harper (1993) examine offsetting behavior in conjunction with mandatory restraint systems (i.e., air bags and seat belts) and 55-mph speed limit laws. They isolate possible offsetting behavior effects via a component model that explicitly distinguishes between occupant fatality, accident, and vulnerability frequencies. The component model is used in this study as well. Peterson et al. (1995) examine offsetting behavior with air bags. They conclude drivers of air bag–equipped cars were disproportionately likely to be the initiator of accidents. Both studies could not reject the offsetting behavior hypothesis.

The works mentioned have contributed greatly to our understanding of how behavioral responses can potentially offset the effectiveness of automobile safety regulations. The following section outlines the methodology used to measure the possible behavioral changes due to CAFE.

III. EMPIRICAL METHODOLOGY

Formulating the Offsetting Behavior Hypothesis

The fatality rate, FR, which is the probably of a fatal accident, can be separated into two components:

$$(1) \qquad FR = (VR) \times (AR),$$

where VR is the vulnerability rate (i.e., the probably of death once an accident occurs) and AR is the accident rate (i.e., the probability of an accident). Thus, VR is simply the ratio of FR and AR.

The central issue is whether drivers of lighter cars are offsetting the greater vulnerability through more alert driving. *The offsetting behavior hypothesis is that the accident rate and passenger car weight are positively correlated.* If CAFE is causing the weight of an average car to fall, then CAFE is simultaneously lowering the frequency of accidents. However, once an accident occurs, the laws of physics take over; thus, we would expect

VR and passenger car weight to be negatively correlated. Again, if CAFE is causing weight to fall, then CAFE is increasing the chances that an accident becomes fatal. Much of the foundation for the empirical approach is based on Peltzman (1975), Crandall et al. (1986), and Chirinko and Harper (1993).

In addition to passenger car weight, from Godek (1997) and Yun (1999), CAFE has increased the ratio of truck miles to passenger miles driven. Because trucks are heavier and offer greater visibility, let us assume that trucks generally offer more safety to their occupants.[9] Thus, as the ratio of truck miles to passenger miles driven increases, according to the offsetting behavior hypothesis, we would expect an increase in the accident rate. However, the effect of more trucks on the vulnerability rate cannot be predicted given the high probability that more accidents will involve both a truck and a car. Although the truck occupants are safer, which means a lower vulnerability rate, the car occupants are worse off, which means a higher vulnerability rate.

Econometric Specification

The next step in testing the offsetting behavior hypothesis is to determine what factors influence the fatality rate, thus influencing the accident and vulnerability rates as well. Certainly, following Crandall et al. (1986), vehicle design, driver demographics, safety regulations, and driver behavior are all relevant variables. The following econometric specification attempts to capture these influences.

The fatality rate, *FR*, measured as the number of fatal accidents per 100 million vehicle miles, is assumed to be a function of the average weight of passenger cars (*WEIGHT*), the variance of *WEIGHT* (*VAR*), the ratio of truck miles to passenger car miles driven (*TRUCK*), the real average earned income per capita (*INCOME*), the number of young and old drivers (*YOUTH*), a measure of alcohol consumption (*ALCOHOL*), an accident cost index (*COST*), average speed (*SPEED*), the real price of gasoline (*PFUEL*), and a safety index (*SAFETY*).

9. Again, this statement is based purely on weight considerations.

This can be represented as

$$(2)\quad FR = f(WEIGHT, TRUCK, VAR, INCOME, YOUTH, ALCOHOL, COST, SPEED, PFUEL, SAFETY).$$

Therefore, the following equation is estimated with ordinary least squares (OLS):

$$(3)\quad FR = \delta_1 WEIGHT + \delta_2 TRUCK + \delta_3 VAR + \delta_4 INCOME + \delta_5 YOUTH + \delta_6 ALCOHOL + \delta_7 COST + \delta_8 SPEED + \delta_9 PFUEL + \delta_{10} SAFETY.$$

All the variables are in logs. Therefore all the coefficients are elasticities, which measures the marginal effect of the independent variables on *FR*.[10] The sample period is from 1963 to 1993.

Given that the fatality rate decomposes into two components,

$$(4)\quad FR = (AR) \times (FR/AR) = (AR) \times (VR),$$

the following two equations are also estimated:

$$(5)\quad AR = \alpha_1 WEIGHT + \alpha_2 TRUCK + \alpha_3 VAR + \alpha_4 INCOME + \alpha_5 YOUTH + \alpha_6 ALCOHOL + \alpha_7 COST + \alpha_8 SPEED + \alpha_9 PFUEL + \alpha_{10} SAFETY.$$

$$(6)\quad VR = \beta_1 WEIGHT + \beta_2 TRUCK + \beta_3 VAR + \beta_4 INCOME + \beta_5 YOUTH + \beta_6 ALCOHOL + \beta_7 COST + \beta_8 SPEED + \beta_9 PFUEL + \beta_{10} SAFETY.$$

10. There is possibility that *SPEED* or *TRUCK* are endogenous with *FR*. In other words, the error term influences the fatality rate, which in turn influence truck miles and average speed. If true, this influence violates a central assumption of OLS. However, because the data set is at the national level, the existence of local endogeneity of these variables would not be as systematic when aggregated. Only if one assumes that the above endogeneity occurs at the national level does the issue become decisive.

The accident rate, *AR*, is measured as the total number of accidents per 100 million vehicle miles. The vulnerability rate, *VR*, is the ratio of *FR* to *AR*, or the ratio of fatal to total accidents. For the log model, $\delta_i = \alpha_i + \beta_i$, for all i due to the use of OLS.

CAFE Hypothesis

Offsetting behavior predicts that the marginal effect of *WEIGHT* and *TRUCK* on *AR* should be positive, but will be negative when estimated on the vulnerability rate, *VR*. Thus the net effect on *FR* will be determined by the relative magnitudes of the *AR* and *VR* coefficients.[11]

Evidence of offsetting behavior is not the only relevant policy issue. In addition, this article seeks to determine the overall impact of CAFE on *AR*, *VR*, and *FR*. On the one hand, the evidence—namely, Crandall and Graham (1989)—supports the assertion that CAFE has lowered the average passenger car weight. On the other hand, the evidence—namely, Godek (1997) and Yun (1999)—supports the assertion that CAFE has increased the ratio of truck to passenger car miles driven.

Formally, the variable *CAFE*, which is a dummy variable from 1975 has the following effect on *WEIGHT* and *TRUCK*:

$$(7) \quad (\%\Delta WEIGHT/\%\Delta CAFE) < 0$$

and

$$(8) \quad (\%\Delta TRUCK/\%\Delta CAFE) > 0,$$

where Δ represents change. In addition, the offsetting behavior hypothesis is that

$$(9) \quad (\%\Delta AR/\%\Delta WEIGHT) = (\partial AR/\partial WEIGHT)(WEIGHT/AR) = \alpha_1 > 0$$

and

$$(10) \quad (\%\Delta AR/\%\Delta TRUCK) = (\partial AR/\partial TRUCK)(TRUCK/AR) = \alpha_2 > 0.$$

Thus, CAFE's total effect on the accident rate is

$$(11) \quad \chi = \alpha_1(\%\Delta WEIGHT/\%\Delta CAFE) + \alpha_2(\%\Delta TRUCK/\%\Delta CAFE).$$

Equation (11) is based on the assumption that CAFE does not change equations (9) and (10). In other words, it is assumed that CAFE has not changed the fundamental relation between passenger car weight and the accident rate as well as the relation between truck miles and the accident rate. See the appendix for details to support this last claim.

Because the sign of the first term in equation (11) is predicted to be negative and the second term is predicted to be positive, the overall sign of χ cannot be known without actually running the model. Additionally, the magnitudes of equations (7) and (8) will affect χ as well. The magnitudes are assumed to be

$$(12) \quad (\%\Delta WEIGHT/\%\Delta CAFE) = -0.140$$

and

$$(13) \quad (\%\Delta TRUCK/\%\Delta CAFE) = 0.0094.$$

The estimate for (12) is obtained from Crandall and Graham's (1989) study, and the estimate for (13) is obtained from Yun (1999).[12] Because these numbers are from other studies, the estimate of χ is a second-best one.[13]

11. The *FR* coefficient will be insignificant if offsetting behavior simply neutralizes the gains in physical safety; a positive and significant coefficient supports the hypothesis that offsetting behavior dominates the physical safety effect.

12. More specifically, CAFE has put 1,690,004 more light trucks and 1,988,590 more passenger cars on the road from 1975 to 1993. In 1993, the total number of trucks and cars in use were 65,260,000 and 121,055,000, respectively. Thus, the ratio of 1,690,004 and 65,260,000 is 0.0258, and the ratio of 1,988,590 and 121,055,000 is 0.0164. Therefore, CAFE is assumed to have increased the trucks to car miles ratio by 0.0094 (= 0.0258 – 0.0164). This approach assumes cars and trucks depreciate at the same rate.

13. The numbers from (12) and (13) are treated as constants in computing the standard error for χ. Ideally, one would also like to compute the standard errors for these "constants" because these are estimates from other studies. Unfortunately, not enough information is provided in Crandall and Graham's (1989) tables to compute the standard error for (12), and (13) is based on a numerous forecasts and averages over time, which makes the computation of the standard error subject to a high degree of complexity and error.

IV. DATA

The following is a detailed description of the data used in this study.

The *ALCOHOL* variable is the total expenditures on alcoholic beverages per person older than 20 years, in millions of dollars, divided by the gross domestic product (GDP) deflator. The source for the alcohol variable is the Economic Research Service (1997).

The *COST* variable is a weighted average of the consumer price indexes (CPIs) for medical care commodities, medical care services, and automobile maintenance and repair. The variable is based on Crandall et al.'s (1986) *COST* index, which is a weighted average of the CPIs for hospital care, doctors' services, and auto repair. The weights given each category remain the same as Crandall et al.'s (0.18, 0.22, and 0.60, respectively).

The *FR* variable is the number of fatal accidents per 100,000,000 vehicle miles. The *AR* variable is the total number of accidents (i.e., fatal, nonfatal, and property) per 100,000,000 vehicle miles. The vulnerability rate, *VR*, is the ratio of *FR* to *AR*. The source is the National Safety Council's *Accident Facts* (various years).

INCOME is real disposable income per capita. *PFUEL* is the price of motor fuel divided by the GDP deflator. Both are from the *Economic Report of the President* (1997).

The *SAFETY* variable is intended to capture the changes in safety since 1966. It is a constructed variable that is the percentage of passenger cars in use that are subject to the safety regulations implemented in 1966 multiplied by a trend term: *SAFETY* = (cars in use produced after 1966/cars in use) × (current year). The variable equals zero from 1963 to 1965, then takes on positive values from 1966. After 1966, the trend term makes the assumption that safety is improved uniformly each year. Due to data limitations,[14] after 1982, the percentage of safety regulated cars is assumed to increase 1%/year until 100% is reached in 1986. The data for cars in use are available from both *Ward's Automotive Yearbook* (Ward's, various years) and *AAMA Motor Vehicle Facts & Figures* (AAMA, various years). Previous studies have used an index of safety regulation developed by Graham, which is not kept current.

The *SPEED* variable is the average speed on main rural roads. The source is the Federal Highway Administration's *Highway Statistics Summary* (various years). The collection of the speed variable has undergone some changes over the sample period.[15] Although this certainly raises questions about the usefulness of the series, it is the only speed series that I am aware of for the sample period. Additionally, this series has been used in many of the prior studies in the auto accident literature, namely, Peltzman (1975) and Crandall et al. (1986). Moreover, speed on urban roads is not available for the sample period. Peltzman (1975, 692) defends the used of rural speed in a footnote stating, "The link between accidents and speed is apparently much more important in rural areas... [S]peed is cited as the principal cause on the order of 1.5, two, and three times more frequently in rural than in urban fatal, injury, and damage accidents, respectively."

TRUCK represents the ratio of truck to passenger car miles traveled for the given year. The variable includes all trucks, not just light trucks. Light truck miles are not available for the sample period. The source is *Automotive News Market Data Book* (Automotive News, 1997).

WEIGHT is the estimated average weight of passenger cars in use in pounds. The series is constructed from these variables: new car weight (domestic and foreign), cars in operation from each model year, and new car sales (domestic and foreign) in a given year. I estimated the domestic average weight in a given year for each major division of the Big Three using weight data from *Ward's Automotive Yearbook*. To compute new car weight for all domestic manufacturers, I used a weighted

14. After 1982, the cars still in use from 1966 and beyond are grouped together. Thus, it is not possible to measure the number of 1966 models in use explicitly.

15. "The data collected from 1945 to 1979 represent only free-moving traffic on level, straight, uncongested sections of rural Interstate highways. Beginning with fiscal year 1980, the data show the speeds of all vehicular traffic. Between 1945 and 1975, speed trend information was collected by vehicle type by various State agencies, normally during the summer months, and submitted to FHWA [Federal Highway Administration] in annual speed trend reports. Since October 1975 all States have monitored speeds at locations on several highway systems, including the Interstate System, as part of the 55 miles per hour speed limit monitoring program. The data are reported to FHWA for all vehicle types combined on a quarterly basis" (*Highway Statistics Summary*, 1985, 176).

average based on sales for each major division. The foreign average weight data are directly from the NHTSA.[16] For the missing years in the foreign weight data set, I use the domestic weight series to interpolate what the missing values would be. Although it is an imprecise technique, I believe it is a better approach than simply excluding foreign weight data altogether, especially because foreign cars were much lighter in the past relative to domestic ones. The sales data are from *Automotive News Market Data Book, 100-Year Almanac* (Automotive News, 1996). The foreign sales data are from the *AAMA Motor Vehicle Facts & Figures*. Finally, the average weight of passenger cars in use series is constructed using the average weight of new cars series and a cars in operation series obtained from both *Ward's Automotive Yearbook* and *AAMA Motor Vehicle Facts & Figures*.

The *WEIGHT* variable is only a measure of average passenger car weight, not trucks. The inclusion of trucks could create endogeneity problems between the *WEIGHT* and *TRUCK* variables. As more trucks are on the road, then the average vehicle weight will increase. Thus, the *TRUCK* variable controls for the increase in truck usage.

The *YOUTH* variable is the ratio of young and old licensed drivers to the rest of the drivers. More specifically, the numerator is the sum of 15–19-year-old drivers and those drivers aged 70 and over; the denominator is the sum of those drivers aged 20 to 69. The licensed driver data are from the *Highway Statistics Summary* (Federal Highway Administration, various years).

V. RESULTS

Offsetting Behavior and CAFE

Table 1 presents the results of the regressions. The positive and significant relationship between passenger car weight and *AR* supports the offsetting behavior hypothesis. According to the model, a 10% increase in weight causes a 15.18% increase in the accident rate. However, once an accident occurs, the vulnerability rate falls by 10.88%, although the coefficient is not significant. This fall is likely the result of the increased crashworthiness that heavier cars provide. In terms of the *FR* equation, the finding is that a 10% increase in weight causes on net a 4.30% increase in the fatality rate; however, the result is not significant. Thus, there is no support for the finding that weight significantly influences the fatality rate.

The variance of weight is significant for the *AR* and *VR* estimations. As the variance increases 10%, the accident rate increases 2.00% and the vulnerability rate decreases 1.85%. In terms of the *AR* estimation, this could be indicating that the net effect from heavy car drivers becoming more aggressive and light car drivers becoming more careful with greater variance is more accidents. In terms of vulnerability, it appears that greater variance improves the safety of the heavier car more than it hurts the safety of the lighter car. Although the *TRUCK* coefficients are of the expected signs, they are insignificant for all three estimations.

Using the estimated coefficients and the assumptions mentioned earlier, CAFE's net effect on the accident rate is a 21.10% decrease. Therefore, CAFE and offsetting behavior have caused less accidents. However, CAFE has increased the vulnerability rate by 14.99%. Overall, the results indicate that CAFE is responsible for a 6.11% net decrease in the annual fatality rate, although this finding is not significant because weight does not have a significant effect on *FR*. Regardless, the findings run counter to the claim that CAFE has cost lives.

Other Independent Variables

From Table 1, the *ALCOHOL* variable is significant in the fatality rate regression. A 1% increase in alcohol expenditures per adult causes a 1.95% increase in the fatality rate. The *COST* variable is insignificant for all three regressions.

The *INCOME* variable is significant for both the fatality and accident rate regressions. A 1% higher income per capita causes a 0.82% fall in the fatality rate and a 1.42% fall in the accident rate. Are these signs consistent with theory? Chirinko and Harper (1993, 273) would expect higher income "to be associated with a greater demand for safety and hence a lower level of occupant fatalities." This statement is based on the

16. Obtained by the generosity of Paul Godek.

TABLE 1
Effects of Car Weight and Truck Miles on the Fatality, Accident, and Vulnerability Rates

	FR	*AR*	*VR*
WEIGHT	0.430	1.518	−1.088
	(1.416)	(1.990)**	(1.394)
TRUCK	−0.093	0.157	−0.251
	(0.410)	(0.453)	(0.623)
VARIANCE	0.014	0.200	−0.185
	(0.669)	(3.923)***	(5.080)***
ALCOHOL	1.955	0.475	1.480
	(2.886)***	(0.350)	(1.304)
COST	0.068	−1.136	1.205
	(0.075)	(0.684)	(0.615)
INCOME	−0.820	−1.420	0.600
	(3.283)***	(2.097)**	(0.931)
PFUEL	0.066	−0.274	0.341
	(0.871)	(1.237)	(2.011)**
SPEED	0.943	1.392	−0.448
	(1.904)*	(2.465)**	(0.605)
YOUTH	−1.412	−0.740	−0.671
	(2.479)**	(0.996)	(1.073)
SAFETY	0.0006	0.006	−0.005
	(0.383)	(0.990)	(0.930)
R^2	0.987	0.939	0.794
Adjusted R^2	0.982	0.914	0.706
Durbin-Watson	1.260	1.602	1.685
RESET test[a]	14.544	0.758	3.453
	[0.001]	[0.394]	[0.077]
χ[b]	−0.0611	−0.2110	0.1499
	[0.0429]	[0.1050]	[0.1084]

Notes: All the variables are in logs. (Sample period: 1963–1993.) Absolute value of *t-statistics are in parentheses. The reported t-statistics are estimated with the* Newey-West heteroskedasticity-consistent standard errors that also corrects for unknown autocorrelation.

[a]Ramsey's RESET test for functional form using the square of the fitted values. The null hypothesis is a correct functional form, and the reported statistic is an *F*-statistic. The probability that the null hypothesis cannot be rejected is in brackets.

[b]χ is the CAFE statistic detailed in section III. The standard error for the statistic is in brackets.

*Significant at the 0.10 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

assumption that safety is a normal good, which I believe is reasonable.

SPEED has a positive and significant impact on the fatality and accident rates. Increasing average speed 1% results in a 0.94% increase in the fatality rate and a 1.39% increase in the accident rate. The *YOUTH* variable is only significant on the fatality rate, where a 1% increase in the relative number of young and old licensed drivers results in a 1.41% fall in the fatality rate. This sign does not seem to conform with the standard view that young and old drivers are less safe drivers. However, being counterintuitive is the cornerstone of offsetting behavior. The above finding could be a result of non-young and nonold drivers exercising greater due care on the aggregate level to account for the increasing number of bad drivers. Finally, the *SAFETY* variable lacks significance and is close to zero for all regressions.

Specification Tests

To check the reliability of the above models, the adjusted R^2s and the Durbin-Watson statistic are also reported in Table 1 for each model. The adjusted R^2 for the *FR*, *AR*, and *VR* models are 0.98, 0.91, and 0.70, respectively. The Durbin-Watson statistic, at the 1% significance points of dL and dU, falls in the inconclusive range for first-order autocorrelation for all three models. Therefore, no attempt is made to correct for first-order autocorrelation.

The reported t-statistics are estimated with the Newey-West heteroskedasticity-consistent standard errors that also corrects for unknown autocorrelation. To check for multicollinearity, a correlation matrix was computed for the independent variables. A number of close correlations were found: *COST* and *WEIGHT*: 0.910; *COST* and *TRUCK*: 0.929; and *COST* and *ALCOHOL*: 0.933. To account for these correlations, Table 2 presents the results from the regressions run dropping the *COST* variable. However, even in the presence of multicollinearity, the OLS estimator remains unbiased and is still the best linear unbiased estimator. On a final note, also reported are the F-statistics from the Ramsey RESET test for functional form. According to this test, the hypothesis of

TABLE 2
Results Dropping the *COST* Variable

	FR	*AR*	*VR*
WEIGHT	0.409	1.865	−1.455
	(2.044)**	(2.563)***	(2.153)**
TRUCK	−0.088	0.064	−0.152
	(0.465)	(0.200)	(0.444)
VARIANCE	0.014	0.212	−0.198
	(0.761)	(4.605)***	(5.629)***
ALCOHOL	1.931	0.884	1.046
	(2.977)***	(0.862)	(1.207)
INCOME	−0.810	−1.593	0.783
	(3.465)***	(2.253)**	(1.158)
PFUEL	0.066	−0.277	0.343
	(0.895)	(1.290)	(2.092)**
SPEED	0.956	1.173	−0.216
	(2.159)**	(2.705)***	(0.436)
YOUTH	−1.429	−0.443	−0.986
	(3.140)***	(0.597)	(1.862)*
SAFETY	0.0006	0.006	−0.006
	(0.373)	(1.101)	(0.976)
R^2	0.987	0.939	0.790
Adjusted R^2	0.983	0.916	0.713
Durbin-Watson	1.253	1.585	1.628
RESET test[a]	12.740	1.290	3.518
	[0.001]	[0.268]	[0.074]
χ[b]	−0.0581	−0.2605	0.2023
	[0.0270]	[0.0994]	[0.0944]

Notes: All the variables are in logs. (Sample period: 1963–1993.) Absolute value of t-statistics are in parentheses. The reported t-statistics are estimated with the Newey-West heteroskedasticity-consistent standard errors that also corrects for unknown autocorrelation.

[a]Ramsey's RESET test for functional form using the square of the fitted values. The null hypothesis is a correct functional form, and the reported statistic is an F-statistic. The probability that the null hypothesis cannot be rejected is in the brackets.

[b]χ is the CAFE statistic detailed in section III. The standard error for the statistic is in brackets.

*Significant at the 0.10 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

a correct functional form is rejected for both *FR* equations at the 1% level.

Comparing Tables 1 and 2, overall the results are similar, in terms of sign and significance changes. The exceptions are the coefficients for *WEIGHT* in the *FR* and *VR* equations, which both become significant at the 5% level, and *YOUTH* in the *VR* equation becomes significant at the 10% level. In Table 2, for a 10% increase in passenger car weight, *FR*, *AR*, and *VR* increases 4.09%, increases 18.65%, and decreases 14.55%, respectively. Therefore, CAFE's overall impact on *FR*, *AR*, and *VR* is a decrease of 5.81%, a decrease of 26.05%, and an increase of 20.23%, respectively. Together, Tables 1 and 2 can be used to estimate an upper and lower bound for the offsetting behavior effect of passenger car weight. CAFE causes the fatality rate to decrease by 5.81%–6.11%, the accident rate to decrease by 21.10%–26.05%, and the vulnerability rate to increase by 14.99%–20.23%.[17]

VI. CONCLUSION

The effects of CAFE on safety have produced interest in and out of the academic community—especially due to the recent debates regarding the merits of increasing the CAFE standards GAO (2000). Driver behavior is recognized as an important factor in assessing safety, and this study is an attempt to measure how CAFE has influenced this behavior. The results are that CAFE has not necessarily cost lives. Although, CAFE has increased the vulnerability of passengers once an accident occurs, there is less likely to be an accident in the first place because drivers are exercising greater due care. This is not to state that there are no detrimental welfare effects on drivers. They are exercising more caution and due care than they would without CAFE.

In terms of policy, offsetting behavior from drivers of lighter cars creates a beneficial moral hazard from the vantage point of automobile insurers. Premiums for small car owners could be set at too high a rate if offsetting behavior effects are not incorporated into the risk estimations.

17. The vulnerability rate finding is similar to Crandall and Graham's (1989) range of 14%–28%.

APPENDIX

RELATING CAFE AND THE ACCIDENT RATE

This appendix is intended to relate the effects of CAFE on the accident rate, *AR*.[18] CAFE does not directly affect the accident rate, but rather indirectly through two channels. The first is through the average weight variable, *WEIGHT*. The second is through the relative truck to passenger car miles driven variable, *TRUCK*. In other words, the average weight and relative truck miles are a function of various factors and CAFE:

$$\text{(A1)} \qquad WEIGHT = f(X, CAFE)$$

$$\text{(A2)} \qquad TRUCK = f(Y, CAFE),$$

where X and Y are independent variables[19] and *CAFE* is a dummy variable from 1975. In other words, letting *WT* represent *WEIGHT* and *TR* represent *TRUCK*:

$$\text{(A3)} \qquad WT = \widehat{WT} + \varepsilon$$

$$\text{(A4)} \qquad TR = \widehat{TR} + u$$

where

$$\text{(A5)} \qquad \widehat{WT} = f(X, CAFE) = \gamma_1 X + \theta_1 CAFE$$

$$\text{(A6)} \qquad \widehat{TR} = f(Y, CAFE) = \gamma_2 Y + \theta_2 CAFE.$$

The CAFE hypothesis is

$$\text{(A7)} \qquad (\partial WT/\partial CAFE) = \theta_1 < 0,$$

$$\text{(A8)} \qquad (\partial TR/\partial CAFE) = \theta_2 > 0.$$

Assuming (A3) and (A4) are estimated using a log-log functional form, θ_1 and θ_2 represent elasticities. Combining the fact that

$$\text{(A9)} \qquad WT = \gamma_1 X + \theta_1 CAFE + \varepsilon,$$

$$\text{(A10)} \qquad TR = \gamma_2 Y + \theta_2 CAFE + u, \text{ and}$$

$$\text{(A11)} \qquad AR = \alpha_1 WT + \alpha_2 TR + \alpha_3 VAR + \alpha_4 INCOME + \alpha_5 YOUTH + \alpha_6 ALCOHOL + \alpha_7 COST + \alpha_8 SPEED + \alpha_9 PFUEL + \alpha_{10} SAFETY + \alpha_{11} v,$$

where v is an error term, the following reduced form is obtained:

$$\text{(A12)} \qquad AR = (\alpha_1\gamma_1 X + \alpha_1\theta_1 CAFE + \alpha_1\varepsilon) + (\alpha_2\gamma_2 Y + \alpha_2\theta_2 CAFE + \alpha_2 u) + \alpha_3 VAR + \alpha_4 INCOME + \alpha_5 YOUTH + \alpha_6 ALCOHOL + \alpha_7 COST + \alpha_8 SPEED + \alpha_9 PFUEL + \alpha_{10} SAFETY + \alpha_{11} v.$$

18. The following can also be used to relate CAFE to *FR* and *VR*.

19. Only one independent variable is used for each to simplify the analysis.

Thus, the effect of CAFE on AR is

$$(\text{A13}) \qquad (\partial AR/\partial CAFE) = \alpha_1\theta_1 + \alpha_2\theta_2.$$

From (A13), there is no reason to suspect that CAFE will affect α_1 or α_2 (i.e., the fundamental relationship between WT and TR on the accident rate), but it will affect AR indirectly through a change, or more specifically a reduction, in average weight and through a change, or more specifically an increase, in relative truck miles.

Note that the equation actually estimated is (A11), not (A12). Specifically, this study estimates α_1 and α_2, while using Crandall and Graham (1989) for an estimate of θ_1 and Yun (1999) for θ_2. Again, assuming (A11) is estimated using a log-log functional form, the right-hand side of (A13) represents an elasticity:

$$(\text{A14}) \qquad (\%\Delta AR/\%\Delta CAFE) = \alpha_1\theta_1 + \alpha_2\theta_2.$$

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