THE EFFECTS OF VARYING SAFETY CONDITIONS ON THE EXTERNAL COSTS OF DRIVING

Thomas L. Traynor
Wright State University

INTRODUCTION

In the past two decades, many studies have evaluated the effects of automobile or road safety conditions on driver behavior. The focus of most of these investigations has been the 'offsetting behavior' (or 'risk compensation') hypothesis, which predicts that drivers offset exogenous improvements in safety conditions by driving less safely. Generally, these studies have attempted to measure the degree to which this offsetting response might (or might not) negate the effect of mandated safety improvements in automobiles. Although the empirical evidence is not uniform, most analyses suggest that the net effect of the regulations on overall highway safety is positive, but less than predicted by traffic safety engineers (whose estimates do not allow for the behavioral modifications by drivers). Also, empirical evidence indicates that non-beneficiaries of automobile safety regulations, such as pedestrians, motorcyclists, and bicyclists are at greater risk.

This paper extends the discussion of compensating behavior by evaluating the effects of such behavior on accident costs. In particular, I evaluate how exogenous changes in the safety level of the driving environment (road conditions, weather, etc.) affect the relative losses suffered by the party at fault and other involved parties. In so doing, the analysis augments previous studies by evaluating the influence of offsetting driver behavior on the distribution of accident costs among victims. The estimates presented here lend support to the hypothesis that improvements in the safety level of driving conditions reduce internal more than external accident costs.

THE RELATIONSHIP BETWEEN SAFETY CONDITIONS AND THE EXTERNAL COSTS OF DRIVING

Description of The External Costs of Driving

The external costs associated with driving can be separated into two categories — those related to driver losses and those incurred by others directly involved. The expected future stream of productivity net of consumption lost due to the driver's death or injury and the uninsured portion of the medical and property damage losses accruing to the driver are both costs imposed on society. Other drivers,

Eastern Economic Journal, Vol. 20, No. 1, Winter 1994

passengers, pedestrians, motorcyclists, and owners of damaged property face the same kinds of productivity, medical, and property losses as the driver and face nonpecuniary costs such as pain and suffering, and any other psychological losses probably not recovered from the at-fault driver. When the at-fault driver is underinsured, does not possess the wealth necessary to finance these losses, or is otherwise able to avoid liability for his unsafe behavior, at least some of the accident costs will remain external. Clearly, as a driver behaves less safely behind the wheel, *ceteris paribus*, the external costs of driving rise, on average, as both the driver and other road users face higher expected accident losses.[1] When underwriting accident losses, insurers reduce external accident costs by differentating between the likely safety effort and ability of drivers on the basis of such factors as age, sex, marital status, residence, driving record, years of experience, and the use classification of the car. This cannot be done perfectly leaving drivers who are relatively more safe than others in the same insurance classification (and are therefore in the same insurance premium category) to partially subsidize those who drive less safely.[2]

External accident costs may be underwritten several ways. Drivers who are not at fault in accidents may be left to underwrite some of their losses themselves through increased insurance premiums, insurance deductibles and co-payments, uncompensated income losses, or the nonpecuniary losses that may be incurred due to the accident. After all, losses suffered by parties not-at-fault are less likely to be underwritten by the at-fault party than losses suffered by the at-fault party. Additionally, society (including insurance companies) may subsidize the losses suffered by the at-fault party through public medical coverage of underinsured at-fault drivers, or may lose the net productivity of the accident's victims.

The Offsetting Behavior Hypothesis and its Effect on the External Costs of Driving

Beginning with Peltzman [1975], economists have argued that regulated (or any exogenous) improvements in the safety characteristics of an automobile decrease the expected cost of any given level of unsafe driving conduct, which induces drivers to reduce their safety effort. Such responses by drivers would partially offset the effects of the original safety improvements. The automobile driver would seek a combination of enjoying the enhanced driving safety afforded by the exogenous safety improvements and pursuing other driving goals which require reduced driving effort.

Additionally, a corollary to the offsetting behavior hypothesis predicts that non-beneficiaries of improved automobile safety, such as motorcyclists and bicyclists (non-occupants) would suffer greater accident costs as a result of sharing the roads with their now more reckless counterparts in automobiles. This reduction in safety for non-occupants serves to further negate the initial benefits of the original safety improvements. Thus the aggregate net effect of the safety improvements on occupants and non-occupants together is theoretically indeterminate, with automobile drivers facing less total risk and non-occupants facing greater risk.

The hypothesis advanced in this paper extends this theory by postulating that even when an exogenous improvement in safety conditions affects all groups simultaneously any reductions in accident costs will come primarily in the form of reduced internal costs (as opposed to reduced external costs). This occurs because drivers, in driving less safely, will choose to do so with regard for only their own costs, regardless of the external cost of their behavior. Consequently, when drivers who wish to reduce travel time consider strategies such as speeding, unsafe passing, or coasting through stop signals, they are more likely to choose the strategy which appropriates the lowest safety risks to themselves regardless of the potential risks faced by others.

To illustrate, consider the following hypothetical example. A driver wishes to spend more driving time observing the scenery along the roadway, operating stereo and temperature controls, or thinking about items other then the task at hand (driving), all of which entail a reduction in driving effort. On average, the driver's choice among the above three options, *ceteris paribus*, will be that which minimizes expected private cost. Since the expected external costs are not a determining factor in the decision, the expected internalized costs of undertaking higher risk behavior driving will be minimized, while the expected external costs, in all likelihood, will not. Thus, more will be done to reduce internal costs as opposed to external costs, and the proportion of accident costs which remain external will rise.

Previous Empirical Investigations

To date, empirical studies have focused almost exclusively on the external costs borne by non-automobile occupants after the introduction of automobile safety regulations. In his original work, Peltzman's time-series estimates indicated that motorcyclists and pedestrians faced higher death rates because of the imposition of National Highway Transportation Safety Administration (NHTSA) automobile safety standards. Peltzman's cross-sectional analysis of state traffic fatality rates, however, failed to confirm the hypothesis that NHTSA safety regulations exposed motorcyclists and pedestrians to greater risks of fatality.

Several ensuing analyses also have evaluated the relationship between additional automobile safety regulations and increased non-car occupant risk. Studies such as Graham and Garber [1984], Crandall, et al. [1986], Evans and Graham [1991], and Garbacz [1991] generally support Peltzman's findings that non-occupants face greater risk when automobile drivers operate in a safer environment. Collectively, although most studies give credence to the hypothesis that automobile safety regulations have deleterious effects on non-occupants, they do not provide universal support. (Blomquist [1988] provides an excellent review of the compensating behavior literature.) This may be due, in part, to the inherent difficulty in accurately estimating motorcycle, bicycle, or pedestrian travel distances, all of which are important in measuring fatality rates. Another potential problem is that these studies are unable to isolate a direct measure of driver behavior, so that estimates of death rates among non-occupants cannot control for other factors which may influence non-occupant death rates such as the changing incidence of helmet use (which might cause non-occupants to behave less safely), driver incompetence in determining the expected costs of their behavior [Blomquist, 1991], or changes in the enforcement of highway safety laws. Additionally, these studies evaluate only a subset of external accident costs by reviewing only parties such as bicyclists, motorcyclists, and pedestrians, and exclude external costs that automobile drivers impose upon each other.

THE MODEL

The data used in the analysis consist of detailed police reports collected by California's State Wide Integrated Traffic Reporting System (SWITRS). Detailed information regarding the time, location, road type, road conditions, weather conditions, parties involved, accident severity, vehicle type, driver characteristics, and driver behavior at the time of the accident as determined by the reporting officer are collected by SWITRS. Due to the large size of the SWITRS data set (it includes every reported highway accident in the state) a random sample of accidents is used.[3] This data is used in conjunction with outside economic data to create a suitable data set. Internal and external accident costs are proxied by the severity of the accident to the at-fault driver and other involved parties respectively, as recorded by the reporting officer.

The model that is estimated in this analysis of cross-section data is a modified form of those used to test the regulation — safety effort relationship with time series data. The general form of the model is

$$E = \alpha + \varphi UNSAFE + \Sigma^{6}_{i=1} \beta_i Z_i + u, \tag{1}$$

where $Z_1 = MALE$
$Z_2 = AGE$
$Z_3 = RISK$
$Z_4 = INCOME$
$Z_5 = PARTIES$
$Z_6 = DRINK.$

The external share of accident costs is represented by *E*, and *UNSAFE* is the safety level of the driving environment at the time of the accident. Lastly, *u* is the stochastic error term. Obviously, both of the variables, *E* and *UNSAFE*, are inherently difficult to measure. Because they are the key factors in this analysis, to compensate, both variables are proxied by several different measures. Three separate measures of the external share of accident costs are used in this paper, each gauging the difference between overall severity of the accident for parties not-at-fault and for the driver at-fault. These measures are based upon the assumption that the losses suffered by those who are not-at-fault are external and losses suffered by the driver at-fault are internal.

The first of the three measures of external accident costs, *INJSHIFT*, is a dummy variable, which is one if the most severe injury in an accident was suffered by parties other than the at-fault party, and zero otherwise. The determination of fault is made by the reporting patrol officer. Although it is possible that errors have been made in making these determinations, there is no reason to believe that, on average, this measure is biased. Since *INJSHIFT* is a binary variable, estimates based on the assumption that the error terms are normally distributed will suffer from heteroscedasticity. Logit analysis is an appropriate method to use in such cases [Greene, 1990, 636-53]. Secondly, external costs are measured by *SHIFT*, defined as the difference between the severity of loss suffered by parties who were not-at-fault and those who were at fault. Specifically, the severity of loss suffered by a party in an accident takes on a value from 1 for property damage accidents to 5 for fatal accidents.[4] *SHIFT* equals the severity of the accident (as measured by the highest degree of loss suffered by any party) minus the severity of the accident to the at-fault party. This is somewhat more comprehensive than *INJSHIFT* since it gauges the degree of difference between the losses suffered by the at-fault party and others. Due to the large number of observations for which *SHIFT* has a value of zero, estimates based on the assumption of a normally distributed error term will be biased. Tobit analysis accounts for the censored distribution of the dependent variable and will be used when *SHIFT* is the dependent variable. Thirdly, *EINJURIES* is the number of injured parties outside of the at-fault party's vehicle. This serves as a completely different measure of external costs relative to internal cost and is based on the proposition that as the number of injuries to parties not-at-fault is increased, the proportion of accident costs that remain external will rise. Again, because of the high number of zero values that occur in *EINJURIES*, Tobit is used to estimate the model. Note that these measures of the dependent variable are meant to proxy changes in external costs relative to changes in internal costs. They are not meant specifically to measure the ratio of external to internal costs.

The first variable included in the vector of control factors, **Z**, is *MALE*, which equals one if the driver at-fault is male and zero otherwise. Since male drivers are known, on average, to be involved in more severe accidents than female drivers, and since more severe accidents are expected to increase the external portion of accident costs, it is expected that the parameter estimate for *MALE* will be positive. *AGE* is the age of the at-fault driver. Since the increased safety risk imposed by younger drivers is attributable to their lack of experience, they are expected to be less able than the general driving population to influence the proportion of accident costs that they face. Thus, the expected sign for the coefficient for AGE is positive. *RISK* represents the expected losses faced by at-fault drivers based on the crash worthiness of their vehicles and carries a value of one through six; one represents the lowest level of crash survivability and six the highest. The make of the vehicle at-fault is used in concert with the federal driver protection rating for that vehicle to create this variable.[5] The estimated parameter for *RISK* is expected to be positive. The variable *INCOME* is the per capita income for the county in which the accident occurred. Increased income increases the value of all time including that of travel, which induces drivers to undertake unsafe behavior in an effort to reduce costly travel time. However, increased income also increases the demand for safer vehicles and safer roads. Thus, there is no *a priori* expected sign for the *INCOME* parameter. *PARTIES* is the number of pedestrians, bicycles or motor vehicles involved in the accident and is included to control for the influence of the sheer size of an accident on its external costs independent of road safety conditions. Since the number of involved parties increases the likelihood that the highest degree of injury will be suffered by a not-at-fault party and should increase the number of not-at-fault injury victims, the parameter estimate should be positive. *DRINK* is one if the driver at-fault had been drinking and zero otherwise. Although the influence that alcohol has on motor vehicle safety is well known, effects of drinking on the proportion of accident costs that are external is unknown. Therefore, there is no expectation regarding the sign of the *DRINK* parameter.

The variable *UNSAFE*, which represents the level of safety on the highway at the time of the accident, is measured using the hazards present at the time of the accident. From these hazards, four dummy variables were created from which three measures of unsafe conditions were developed. The first of these four dummy variables is *RAMP*, which indicates the existence of an entrance ramp or intersection at the accident scene. Next, *ROADCOND* denotes the existence of slippery, rough, or otherwise hazardous road conditions. Third, *VISIBILITY* signifies weather and lighting conditions which hinder the driver's ability to drive safely by negatively influencing visibility. Lastly, *TRAFFIC* indicates the presence of heavy traffic at the time of the accident.[6]

The first measure of safety conditions, *HAZARD*, is a dummy variable which equals one if any one or more of the above four conditions existed at the time of the accident. The expected sign for *HAZARD* is negative. Note that thus far, the hypothesis has been expressed as a positive relationship between improved driving conditions and external costs. Due to the form in which driving conditions are measured, the hypothesis tested is expressed as the inverse relationship between driving hazards and external costs.

Second, to measure the difference between the presence of a single hazard and multiple hazards, highway safety conditions are defined by three separate dummy variables. *1HAZARD* is equal to one if one of the above hazards is present at the time of the accident and zero otherwise. *2HAZARDS* is equal to one if two of the above hazards are existent at the time of the accident and zero otherwise. And *>2HAZARDS* is a dummy variable which has a value of one if the at-fault driver faced three or all four of the above hazards at the time of the accident and zero otherwise. The use of these three variables allows a comparison among the relative influences of differing numbers of interacting hazards upon external costs. It is expected that all three of these variables will have negative parameter estimates.

And third, a weighted sum of the above four conditions is developed to create a single variable (*DANGER*) which measures the overall level of danger facing the at-fault driver at the time of the accident. The equations which use *DANGER* to represent the safety of driving conditions compute a single estimate that represents the influence of increasingly unsafe driving conditions on the external portion of accident losses. This is a more comprehensive measure than *HAZARD* because it varies with the number and quality of the hazards presented to the at-fault driver at the time of the accident. Because of the dearth of available information regarding the relative importance of various road safety conditions, a determination cannot be made, *a priori*, of how to weight the individual factors when developing this variable. To circumvent this problem, a model was estimated with accident severity as the dependent variable and *RAMP*, *ROADCOND*, *VISIBILITY*, *TRAFFIC*, and the vector **Z** as independent variables. Accident severity, *S*, equals one for property damage only accidents, two if any victims have complaints of pain, three if any of the victims have visible injuries, four if anyone suffers a severe injury, and five for fatal accidents. The resulting estimates were:[7]

$$\begin{array}{llllll} S = -2.353 & -\ 0.336RAMP & -\ 0.026ROADCOND & -\ 0.033VISIBILITY & -\ 0.183TRAFFIC & \\ \quad (.614) & \quad (.130) & \quad (.297) & \quad (.132) & \quad (.214) & \\ & & & & & \\ +\ 0.232Z_1 & +\ 0.005Z_2 & +\ 0.132Z_3 & -\ 0.0001Z_4 & +\ 0.703Z_5 & +\ 0.012Z_6 \\ \quad (.135) & \quad (.003) & \quad (.046) & \quad (.00005) & \quad (.078) & \quad (.160) \end{array}$$

From these estimates, the relative size of the estimated parameters for *RAMP*, *ROADCOND*, *VISIBILITY*, and *TRAFFIC*, are used to weight the presence of a ramp or intersection by 13.0, the presence of hazardous road conditions by 1.0, the presence of poor visibility by 1.3, and the presence of heavy traffic by 7.0. These weights equal the ratio of each of the parameter estimates for *RAMP*, *ROADCOND*, *VISIBILITY*, and *TRAFFIC* to the parameter for *ROADCOND*. Thus, *DANGER* = 13.0(*RAMP*) + *1.0(ROADCOND)* + 1.3(*VISIBILITY*) + 7.0(*TRAFFIC*). Although there is no standard procedure for the development of a weighted-sum variable such as *DANGER*, this technique should avoid problems that might arise from arbitrarily defining the variable, and together with the other proxies of road safety that are used, should provide a reasonably accurate representation of the relationship between safety conditions and the external costs of driving. The parameter estimate for *DANGER* should be negative.

In total, nine equations are estimated, each representing a different permutation of the various proxies developed for the external proportion of accident costs and the safety of the roads at the time of the accident. Summary statistics for all of the variables are presented in Table 1.

TABLE 1
Summary Statistics

Variable	Mean	Std Dev
INJSHIFT	0.8199737	0.3842935
SHIFT	0.2601840	0.6144088
EINJURIES	0.3920280	0.8462256
1HAZARD	0.3556742	0.4788214
2HAZARDS	0.2790188	0.4486150
>2HAZARDS	0.3350850	0.4721237
RAMP	0.0551905	0.2284018
ROADCOND	0.4949628	0.5000842
VISIBILITY	0.4515988	0.4977608
TRAFFIC	0.9351730	0.2462743
DANGER	8.6552781	3.7472282
MALE	0.7275515	0.4453170
AGE	32.2457293	15.0727006
RISK	2.9399912	1.2023164
INCOME	8598.78	1070.69
PARTIES	1.8830486	0.7741932
DRINK	0.1752081	0.3802282

N = 2283

THE ESTIMATES

Estimates of the three logit equations in which *INJSHIFT* is the dependent variable are presented in columns 2, 3, and 4 of Table 2. For all three equations, the Chi-square goodness-of-fit criteria are satisfied.[8] In column 2, all parameter estimates have their expected signs, and with the exceptions of *AGE* and *DRINK*, differ significantly from zero at the 90 percent level of confidence.[9] Most importantly, the parameter for *HAZARD* is negative and significant as was hypothesized indicating that on average, road hazards, in any form or combination, significantly hinder the ability of drivers to avoid internal accident costs (reducing the external portion of accident costs).

The estimates listed in column 3 of Table 2 also have the expected signs, and once again, all of the parameters except those for driver age and drinking are significantly different from zero using the standard criteria. The three key parameters in this equation (*1HAZARD*, *2HAZARDS*, and *>2HAZARDS*), have a couple of interesting implications. First, as predicted by theory, all three parameter estimates are negative and significantly different from zero, indicating that the presence of any hazards reduces external costs relative to internal costs. Second, as the number of hazards facing the at-fault driver rises, the external proportion of losses falls. This indicates that, as the number of hazards increases, each additional hazard faced by the driver has a diminishing marginal effect on the likelihood that most accident costs are external. Lastly, column 4 of Table 2 lists estimates which all have the expected signs and which, again with the exception of driver age and

TABLE 2
Logit Estimates

Dependent Variable: INJSHIFT

Variable	(1)	(2)	(3)
INTERCEPT	-1.9890[a] (-3.176)	-1.9733 (-3.139)	-2.3559[a] (-4.223)
HAZARD	-.5355[a] (-1.918)	——	——
1HAZARD	——	-.5114[a] (-1.782)	——
2HAZARDS	——	-.1102[a] (-1.864)	——
>2HAZARDS	——	-.0278[a] (-1.904)	——
DANGER	——	——	-.0260[a] (-1.503)
MALE	.2373[a] (1.759)	.2387[a] (1.768)	.2322[a] (1.722)
AGE	.0057 (1.583)	.0057 (1.583)	.0056 (1.600)
RISK	.1319[a] (2.849)	.1313[a] (2.836)	.1329[a] (2.870)
INCOME	-.00014[a] (-2.800)	-.00014[a] (-2.800)	-.00013[a] (-2.600)
PARTIES	.7098[a] (9.170)	.7076[a] (9.118)	.7039[a] (9.024)
DRINK	.0145 (.0923)	.0161 (.1021)	.0127 (.0808)
Model Chi-square	133.898	136.369	134.237
Concordant %	68%	68%	68%
N = 2283			

[a] Indicates significance at the 5 percent level or better for a one-tailed test.

alcohol consumption, are significantly different from zero. And the parameter estimate for *DANGER* is negative and significant, as was hypothesized, indicating that as the overall safety conditions improve, there is an increasing likelihood that the external costs will be larger than the internal costs. As mentioned before, the parameter estimates for the variables *AGE* and *DRINK* are probably statistically insignificant in most estimated equations because age and alcohol use probably are not as significant determinates of the relative costs of accidents as they are of the aggregate costs of accidents.

Table 3 is organized similarly to Table 2, but with *SHIFT* as the dependent variable. In the second column, all of the parameter estimates have the expected signs, and once again, the proxy for safety conditions, *HAZARD*, yields a significant negative coefficient, which is consistent with the thesis of this paper. Column 3 also lists estimates consistent with expectations and the parameter estimates for *1HAZARD*, *2HAZARDS*, and *>2HAZARDS* are negative and decline in value, indicating that as the number of hazards rises, each additional hazard has a diminishing marginal effect on the degree of difference between the severity of the accident to the at-fault and not-at-fault parties. An interesting point of fact is that the *t*-statistics rise markedly as the number of hazards present at the time of the accident rises. This simply indicates that higher numbers of road hazards are more likely to actually influence the dependent variable. Finally, the last column in Table 3 lists estimates which all have the expected signs. The parameter estimate for *DANGER* is negative and significant, as was hypothesized. This indicates that as conditions become relatively more safe, at-fault drivers bear a smaller share of accident losses.

As before, Table 4 presents the resulting estimates of the tests for which *EINJURIES* is the dependent variable. The parameter estimates listed in the second column all have the expected signs, and with the exception of driver sex, all coefficients are statistically different from zero at the 90 percent level of confidence. *HAZARD* produces a significant negative coefficient, which is consistent with the main proposition of this paper. The estimates presented in column 3 of Table 4 are also consistent with expectations, and except for driver sex, *1HAZARD*, and *2HAZARDS*, are statistically significant. The declining magnitude of the parameter estimates for *1HAZARD*, *2HAZARDS*, and *>2HAZARDS* once again signifies that injuries suffered by parties outside the at-fault driver's car decrease as the number of hazards faced by the drivers increases. The coefficients for *1HAZARD* and *2HAZARDS* are not significantly different from zero, revealing that one hazard alone or two hazards alone do not significantly influence external costs as measured by the number of injuries suffered. As in Table 3, the *t*-statistics are progressively higher as the number of hazards present rises, simply indicating that higher numbers of hazards are more likely to affect *EINJURIES* than low numbers of hazards. Finally, the last column in Table 4 lists estimates which all have the expected signs and which are significantly different from zero with the exception of driver sex. And the parameter estimate for *DANGER* is negative and significant, as

TABLE 3
Tobit Estimates

Dependent Variables: *SHIFT* Variable	(1)	(2)	(3)
INTERCEPT	-2.3476[a] (-3.146)	-2.3255[a] (-3.108)	-2.7146[a] (-4.131)
HAZARD	-0.5950[a] (-1.718)	___	___
1HAZARD	___	-0.5337 (-1.502)	___
2HAZARDS	___	-.1233[a] (-1.689)	___
>2HAZARDS	___	-0.0327[a] (-1.827)	___
DANGER	___	___	-0.0335[a] (-1.692)
MALE	0.2610[a] (1.656)	0.2645[a] (1.677)	0.2522 (1.600)
AGE	0.0067 (1.558)	0.0066 (1.558)	0.0067 (1.558)
RISK	0.1699[a] (3.007)	0.1683[a] (2.894)	0.1702[a] (3.012)
INCOME	-0.0001[a] (-1.667)	-0.0002[a] (-3.333)	-0.0001[a] (-1.667)
PARTIES	0.7453[a] (8.862)	0.7415[a] (8.806)	0.7376[a] (8.729)
DRINK	0.0512 (.2790)	0.0544 (.2950)	0.0512 (.2789)
Standard Error	0.2104	0.2317	0.2138
Log Likelihood	-1536.80	-1536.51	-1536.79
N = 2283			

[a] Indicates significance at the 5 percent level or better for a one-tailed test.

TABLE 4
Tobit Estimates

Dependent Variable: *EINJURIES*

Variable	(1)	(2)	(3)
INTERCEPT	-1.7260[a] (-2.456)	-1.6733[a] (-2.375)	-1.9858[a] (-3.276)
HAZARD	-0.4913[a] (-1.424)	—	—
1HAZARD	—	-0.3925 (-1.112)	—
2HAZARDS	—	-0.1113 (-1.539)	—
>2HAZARDS	—	-0.0286[a] (-1.602)	—
DANGER	—	—	-0.0318[a] (-1.700)
MALE	0.0259 (.1774)	0.0347 (.2373)	0.0217 (.1485)
AGE	0.0112[a] (2.800)	0.0110[a] (2.750)	0.0112[a] (2.800)
RISK	0.1055[a] (1.957)	0.1026[a] (1.903)	0.1052[a] (1.952)
INCOME	-0.0002[a] (-3.333)	-0.0002[a] (-3.333)	-0.0002[a] (-3.333)
PARTIES	0.8216[a] (10.132)	0.8154[a] (10.154)	0.8125[a] (10.081)
DRINK	0.6620[a] (3.990)	0.6720[a] (4.031)	0.6681[a] (4.020)
Standard Error	0.1847	0.2065	0.1880
Log Likelihood	-1995.62	-1994.78	-1995.15
N = 2283			

[a] Indicates significance at the 5 percent level or better for a one-tailed test.

was hypothesized, again indicating that as conditions become relatively safer, the share of injuries accrued to the not-at-fault parties rises.[10]

In all three tables, the parameter estimates for *RISK* are all positive and statistically significant, which lends further support to the hypothesis that safer driving conditions (in this case, safer vehicles) create greater relative external accident costs.

In aggregate, the results of the nine tests discussed above signify that there is indeed a positive relationship between the safety level of the driving environment and a driver's ability to ultimately influence the relative portion of accident costs that remain external to his or her unsafe behavior. Several interesting conclusions can be drawn from these tests. First, hazardous driving conditions, in any form or combination, significantly hamper a driver's ability to pass the costs of his driving behavior onto others. Or conversely, the elimination of any and all driving hazards will increase the external segment of accident costs. Second, although this ability is more strongly affected by the presence of multiple hazards than it is by the presence of a single hazard, the addition of each subsequent hazard has a decreasing influence upon the portion of accident costs which are external. And third, as the general level of safety present on the roads improves, the portion of accident costs that are external rises. These conclusions are implied by estimates indicating that drivers respond to improved driving conditions in ways which ultimately reduce the part of accident costs accruing to themselves.

In an effort to determine if the above changes in external costs relative to internal costs are primarily in the form of changes to external costs or changes to internal costs, the equations that were estimated in Table 3 (with *SHIFT* as the dependent variable) were divided into two equations each. In one case, the dependent variable is equal to the severity level of the accident to the at-fault driver, which proxies internal accident costs. In the other, the dependent variable is equal to the overall level of accident severity, which proxies external accident costs. As reported in Table 5, the results are mixed. In the first two columns (in which safety conditions are measured by *HAZARD*) the parameter estimate is significantly positive when internal costs are the dependent variable and close to zero when the dependent variable is the external costs of the accident. This implies that changes in the ratio of external to internal costs accrue primarily through changing internal costs. The third and fourth columns (in which safety conditions are measured by *1HAZARD*, *2HAZARDS*, and *>2HAZARDS*) also indicate that changes in external relative to internal costs derive primarily from changes in internal costs. However, the final two columns indicate that when *DANGER* is used to represent changing safety conditions, external costs fall while internal costs do not. Although interesting, the results shown in Table 5 present mixed evidence regarding the source of the relationship between road hazards and the distribution of accident costs among victims. Future research may be able to evaluate this question better with more appropriate data.

TABLE 5
Tobit Estimates of Separate External and Internal Effects

	Dependent Variable					
Variable	*EXTER.*	*INTER.*	*EXTER.*	*INTER.*	*EXTER.*	*INTER.*
INTERCEPT	-0.1687 (-0.2988)	-1.1608 (-1.2465)	-0.1375 (-0.2429)	-1.0827 (-1.1587)	0.1235 (0.2639)	0.4716 (0.6972)
HAZARD	0.1021 (0.3373)	1.3995 (2.2524)	—	—	—	—
1HAZARD	—	—	0.1699 (0.5509)	1.5065 (2.4029)	—	—
2HAZARDS	—	—	0.02003 (0.3185)	0.2780 (2.1941)	—	—
>2HAZARDS	—	—	0.00074 (0.0475)	0.0628 (1.9948)	—	—
DANGER	—	—	—	—	-0.0186 (-1.2876)	-0.0114 (-0.5398)
MALE	-0.1594 (-1.3774)	-0.6439 (-3.8566)	-0.1565 (-1.3510)	-0.6408 (-3.8353)	-0.1622 (-1.4016)	-0.6459 (-3.866)
AGE	0.0049 (1.4762)	0.0040 (0.8093)	0.0048 (1.4507)	0.0038 (0.7747)	0.00495 (1.4804)	0.00416 (0.8412)
RISK	0.0548 (1.2996)	-0.07549 (-1.2208)	0.0522 (1.2349)	-0.0811 (-1.3089)	0.0537 (1.2727)	-0.0778 (-1.2558)
INCOME	-0.000093 (-1.9702)	-0.000032 (-0.4676)	-0.000093 (-1.9745)	-0.000033 (-0.4868)	-0.000093 (-1.977)	-0.000044 (-0.6459)
PARTIES	0.0157 (0.2400)	-0.8651 (-7.6350)	0.00775 (0.1175)	-0.8837 (-7.723)	-0.00066 (-0.0100)	-0.9028 (-7.846)
DRINK	0.9604 (7.3958)	1.4926 (8.2631)	0.9583 (7.349)	1.4892 (8.211)	0.9756 (7.5046)	1.5261 (8.408)
Standard Error	0.1382	0.2275	0.1565	0.2515	0.1401	.2258
Log Likelihood	-2717.51	-1885.50	-2716.69	-1884.51	-2716.73	-1888.31
N = 2283						

SUMMARY

This article extends the analysis of compensating driver behavior by studying the relationship between highway safety conditions and the portions of accident costs that are internal and external respectively. Nine equations were developed to test this hypothesis, which together provide a comprehensive evaluation of the relationship between road safety conditions and the proportion of accident losses that are external.

The resulting estimates lead to the conclusion that, controlling for other influences, as driving conditions become safer accidents become relatively more injurious for not-at-fault drivers than for at-fault drivers. This result carries important implications for policymakers wishing to reduce the costs of road transportation. It appears that exogenous improvements to automobile or road safety have a stronger effect on the internal costs of accidents than on the external costs of accidents. Thus, new policies should focus more on methods that internalize a greater share of accident costs, or at least primarily reduce the external costs of surface transportation. At the very least, though, it appears that in developing transportation safety policies, policymakers must concern themselves with the external costs of drivers' actions.

NOTES

1. Calfee and Rubin [1992] provide a complete discussion of the nonpecuniary costs of accidents, while Jones-Lee [1990] discusses the external costs of driving, including estimates of these costs under various conditions.
2. For a more complete discussion of actuarial methods used by the automobile insurance industry, see Lemaire [1985, 39-56].
3. In order to accommodate computing space limitations, a random sampling of 10 percent, 2283 observations of the SWITRS data base was used. Measures for traffic density, which is an important variable in this analysis, are not available for the years following 1978. Thus accidents from 1978 were evaluated. Since the hypothesis is testing the human behavioral response to general safety conditions, the age of the data does not present any potential problems with the estimates.
4. The values given to an accident's severity are 1—property damage only, 2—complaint of pain, 3—visible injury, 4—severe injury, 5—fatal.
5. This variable equals the driver protection rating for that vehicle published in *Consumer Reports* [1981]. The crash tests used to generate these ratings were conducted by the NHTSA.
6. Road conditions are defined as hazardous if they are slippery, wet, rutted, rough, have holes, are under construction, have narrowed width, or are otherwise obstructed. *VISIBILITY* denotes the presence of darkness, rain, snow, or fog at the time of the accident. *TRAFFIC* is one if the accident occurred during rush hour (6 a.m. to 9 a.m. or 4 p.m. to 7 p.m., Monday through Friday)in population areas of 100,000 or more, or in traffic conditions specifically designated as stop-and-go in the police report.
7. Due to the large number of observations for which S is equal to zero, Tobit estimation is used. The standard errors are given in parentheses.
8. The concordant percentage represents the percentage of observations for which the predicted probability is statistically concordant with the actual value [Maddala, 1992].
9. Although the parameter estimates for *AGE* are frequently not different from zero, they are at the very least, very nearly significantly different from zero for a 10 percent rejection region of a two-tailed test. Note that the dependent variables *INJSHIFT* and *SHIFT* measure relative external to internal costs of accidents, rather than the absolute costs of accidents. The differential influence of driver age and drinking might not be as strong as it would be for a more absolute measure, such as *EINJURIES*.

10. Drivers may respond to less safe driving conditions by not driving, a response which is not measured by this accident-specific data set. Fortunately, this problem does not negatively influence the conclusions reached in this paper. First, the intent of the paper is to review the effect of safety changes upon the portion of aggregate accident costs that are external. Second, since the decision to not drive results in zero accident costs, if average external costs are greater than average internal costs the decision not to drive will reduce external costs more than internal costs. Since the mean value of *INJSHIFT* is .8199, the external costs on average are higher than the internal costs of accidents. Thus, the reported coefficients are biased toward zero and the true relationship is even stronger than reported here.

REFERENCES

Blomquist, G. C. *The Regulation of Motor Vehicle and Traffic Safety.* Boston: Kluwer Academic Publishers, 1988.

__________. Motorist Use of Safety Equipment: Expected Benefits or Risk Incompetence. *Journal of Risk and Uncertainty*, April 1991, 135-52.

Calfee, J. E. and Rubin, P. H. Some Implications of Damage Payments for Nonpecuniary Losses. *Journal of Legal Studies*, June 1992, 371-411.

Crandall, R. W., Gruenspect, H. K., Keeler, T. E., and Lave, L. B. *Regulating the Automobile.* Washington, D.C.: The Brookings Institution, 1986.

Evans, W. N., and Graham, J. D. Risk Reduction or Risk Compensation? The Case of Mandatory Safety-Belt Use Laws. *Journal of Risk and Uncertainty*, April 1991, 61-73.

Garbacz, C. Impact of the New Zealand Seat Belt Law. *Economic Inquiry*, April 1991, 310-16.

Graham, J. D., and Garber, S. Evaluating the Effects of Automobile Safety Regulation. *Journal of Policy Analysis and Management*, June 1984, 206-24.

Greene, W. H. *Econometric Analysis*, New York: Macmillan Publishing Co., 1990, 727-753.

Jones-Lee, M. W. The Value of Transport Safety, *Oxford Review of Economic Policy*, 1990, 39-60.

Lemaire, J. *Automobile Insurance: Actuarial Models*. Hingham, MA: Kluwer-Nijhoff Publishing, 1985.

Maddala, G. S. *Introduction to Econometrics*, 2nd ed., New York: Macmillan Publishing Co., 1992, 332-35.

Peltzman, S. The Effects of Automobile Safety Regulation. *Journal of Political Economy*, August 1975, 677-725.

Traynor, T. L. The Peltzman Hypothesis Revisited: An Isolated Evaluation of Offsetting Driver Behavior. *Journal of Risk and Uncertainty*, October 1993, 237-47.

Which Cars do Best in Crashes? *Consumer Reports*, April 1981, 188-92.