Transportation Research Forum

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Source: *Journal of the Transportation Research Forum*, Vol. 55, No. 1 (Spring 2016), pp. 17-27
Published by: Transportation Research Forum
Stable URL: http://www.trforum.org/journal

The Impact of Driving Knowledge on Motor Vehicle Fatalities

by Walter O. Simmons, Andrew M. Welki, and Thomas J. Zlatoper

This paper analyzes the influence of driving knowledge on highway safety by estimating regression models on U.S. state-level data over six years (2005 through 2010). The models incorporate a representative set of motor vehicle fatality determinants. Driving knowledge—as measured by performance on the GMAC Insurance National Drivers Test—has a statistically significant life-saving effect. Negatively related to the motor vehicle death rate and statistically significant are: real per capita income, precipitation, seat belt use, and a linear trend. Statistically significant positive associations with the rate are found for: the ratio of rural to urban driving, temperature, the percentage of young drivers, the percentage of old drivers, and alcohol consumption.

INTRODUCTION

While trending downward in recent years, annual motor vehicle deaths in the U.S. remain large in number. For example, they totaled 43,510 in 2005 and 32,999 in 2010 (National Highway Traffic Safety Administration [NHTSA] 2013, p. 5). Of interest to policy makers are initiatives that can lead to further declines in roadway fatalities.

Some researchers have suggested that efforts to increase driving knowledge could improve road safety. For example, Amarasingha and Dissanayake (2013) note that education programs that increase awareness of unsafe practices (e.g., failure to yield right of way, driving too fast for conditions) could reduce risk for young drivers. However, the effectiveness of such initiatives requires that increased knowledge results in safer driving.

Does greater driving knowledge contribute to safer highway travel? This paper addresses this question. Specifically, it estimates the relationship between driving knowledge, as measured by performance on the nationally administered GMAC Insurance National Drivers Test, and U.S. motor vehicle fatalities.[1] The estimation controls for the influence of a representative collection of highway death determinants.

This study has the following format: The first section discusses previous research on the determinants of U.S. motor vehicle deaths with a particular focus on the impact of driver education. A model that explains these deaths is specified in the second section. The third section describes the data set used in the analysis. Regression estimates of the model are reported and discussed in the fourth section. The final section summarizes the paper's findings.

BACKGROUND

There has been considerable research on the determinants of U.S. motor vehicle safety. Loeb, Talley and Zlatoper (1994) summarize the collective findings of several selected empirical studies to that point in time. The studies typically use historical data and multivariate statistical techniques (e.g., multiple regression analysis) to estimate the impact of various potential determinants on safety outcome measures (e.g., highway accidents, injuries and fatalities). The determinants can be categorized as economic (e.g., accident cost, income, fuel price, economic activity); driver-related (e.g., alcohol use, speed, gender, age, amount of travel); vehicle-related (e.g., vehicle type, size, mandated vehicle safety features, age); highway-related (e.g., type of roadway, location); environmental (e.g., traffic density, weather, lighting, altitude); and other considerations (e.g., hospital access, geographical area, and time factors).[2] Some studies analyze the effectiveness of deterrent policies (e.g., motor vehicle inspection, minimum legal drinking age, speed limits, seat belt laws).

During the last 20 years, researchers have analyzed the effect of cell phone use on highway safety. Other determinants considered include education levels, crime rates, and suicide rates. In addition to conventional techniques such as multiple linear regression, Bayesian estimation methods have been increasingly utilized. Blattenberger, Fowles, and Loeb (2013) summarize the collective findings of the more recent empirical work.

This body of highway safety research includes efforts to understand how and if drivers' tests and the driver education process affect road safety. Two notable research strands of driver education are the written test and the graduated licensing programs (GDL). Research about the written driving test comprises the early stages of the analysis, while more recent work emphasizes contributory factors and the GDL program. The discussion here follows that order.

One anticipates that a better understanding of the "rules of the road" should create a safer driving environment. Arthur and Doverspike (2001) extended that idea to examine the role of driver personality and its effect on crashes. Their work adds to written driver's test research by Hill and Jamieson (1978); McKnight and Edwards (1982); and Struckman-Johnson and others (1989). Arthur and Doverspike (2001) note that support for driving knowledge as a safety enhancer is equivocal. They, however, find that a driver personality variable, conscientiousness, is negatively related to the number of crashes.

More recent research focuses on changes in the driver education process, more specifically, the experiential portion of young driver development. Over time, all states moved to a GDL process. These activities frame the aspiring driver's road experience prior to acquiring full driving privileges. Each GDL stage works on specific circumstances. The ultimate goal of the driver preparation process is a combination of practical physical experiences and a knowledge of the "rules of the road" that produces a driver less likely to contribute to an unsafe world for the driving public.

Many studies examined the effects of GDL programs on reducing teenage crashes. Typically, each study focused on the experience of a specific state. States analyzed are: Missouri by Bernard and Sweeney (2015); Kansas by Amarasingha and Dissanayake (2013); Maryland, Florida, and Michigan by Ehsani and others (2013); Utah by Hyde and others (2005); and Georgia by Rios and others (2006). The Bernard and Sweeney paper (2015), which examines the contributing circumstances associated with teenage driver fatalities, provides a good list of analyses of this type.

Bernard and Sweeney (2015) use data linking contributory factors to crash fatalities. Contributory factors can then inform the types of changes needed to enhance the effectiveness of GDL programs. While not universal across all state studies, the research results suggest that GDL programs reduced crash rates for teenage drivers.

This paper extends previous work in this area in a number of ways. It revisits the effect of written drivers' tests on road safety. Of particular note is the use of data on a common test collected from drivers across all 50 states. This permits interstate comparison as a standard measure of driving knowledge is utilized.

Additionally, although individual accident data are not used, the state-level (aggregated) data includes variables that control for micro-level causal factors (e.g., alcohol use). The explanatory factors are representative of the types used in the larger body of highway safety research. Embedded within these variables are factors examined in state-specific studies to inform the GDL process.

MODEL

Four categories of explanatory factors are explicitly included in the model: economic conditions, locational factors, weather conditions, and driver characteristics. The model's general form is:

(1) DEATHRT = f(INCOME, RURURB, TEMP, PRECIP, YOUNG, OLD, ALCOHOL, SBELTUSE, KNOWLEDGE)

where	DEATHRT	=	motor vehicle death rate
	INCOME	=	consumer income
	RURURB	=	rural-urban driving mix
	TEMP	=	temperature
	PRECIP	=	precipitation
	YOUNG	=	young drivers
	OLD	=	old drivers
	ALCOHOL	=	alcoholic intoxication while driving
	SBELTUSE	=	seat belt use
	KNOWLEDGE	=	driving knowledge

The expected relationship between each explanatory factor and the death rate is explained below.

Income represents economic conditions. Its impact on highway fatalities is uncertain a priori. Higher income should increase the demand for safety and driving intensity, assuming that both are normal goods.[3] Due to these offsetting considerations, Peltzman (1975) conjectures that the direction of the relationship between income and deaths is unclear. Loeb, Talley, and Zlatoper (1994, pp. 18-19) report that time-series studies provide evidence of a positive relationship, while cross-sectional and pooled analyses indicate a negative association.

Speeds are generally higher during rural travel than during urban travel. As a result, the chance of death is likely greater when an accident occurs in a rural location. Loeb, Talley, and Zlatoper (1994, pp. 32) cite time-series and cross-sectional studies providing statistically significant evidence of inverse associations between motor vehicle fatality measures and the proportion of urban highway travel. Given these findings, the locational measure employed here—the ratio of rural to urban travel—is anticipated to be positively related to the death rate.

Regarding weather conditions, Loeb, Talley, and Zlatoper (1994, p. 34) report that cross-sectional analyses find that temperature and precipitation have statistically significant positive and negative associations, respectively, with highway fatality measures. Higher temperatures may encourage more driving and faster speeds, while more precipitation may foster the opposite. Based on these results, the same associations are expected in this study.

Age is one of the driver characteristics accounted for here. Younger motorists have less experience and are more inclined to take more risks; and older drivers are subject to deterioration in physical factors (e.g., eyesight and reflexes) that influence driving safety. Due to these considerations, younger and older drivers may be more susceptible to motor vehicle accidents and deaths. However, Loeb, Talley, and Zlatoper (1994, pp. 24-25) note that the results in statistical studies on the relationships between these two age groups and death measures are mixed. Given the inconclusive evidence, the anticipated relationship between the extent of driving involvement by the youngest and oldest age groups and highway fatality measures is uncertain a priori.

Alcohol usage is another driver characteristic included in this analysis. According to conventional wisdom, intoxicated drivers are more likely to be involved in fatal crashes. Loeb, Talley, and Zlatoper (1994, pp. 20-21) catalogue research evidence of a significant direct relationship between alcohol consumption and motor vehicle death measures in the U.S. The same association is anticipated in this study.

Another driver characteristic accounted for is seat belt use. According to NHTSA (2001, Exhibit 6) estimates, the manual lap-shoulder belt is highly effective in saving lives of car drivers. In contrast, Garbacz (1990) finds that seat belt use has no statistically significant effect on total or driver or overall occupant (drivers and passengers) deaths, and it has a life-taking impact on non-occupants (pedestrians, cyclists, and motorcyclists) and passengers.[4] Given the mixed evidence, the expected relationship between highway fatality rates and seat belt use is uncertain a priori.

Driving knowledge is represented by performance on the GMAC Insurance National Drivers Test described in the next section. Two state-level performance measures are utilized in this analysis: test average (TESTAVG) and test rank (TESTRANK). Assuming that individuals with greater knowledge drive more safely, motor vehicle death measures are expected to be negatively related to TESTAVG and positively related to TESTRANK.[5]

In addition to the four categories of explanatory factors discussed above, this study controls for spatial and temporal considerations. The former pertains to geographic areas of the U.S., while the latter corresponds to a time trend.

DATA

An online survey to test the knowledge of general driving safety rules among a nationally representative sample of licensed drivers in the U.S. is used in this study. In partnership with TNS (the world's largest custom research agency), General Motors Acceptance Corporation (GMAC) conducted the survey from 2005 to 2011 to determine how many American drivers would meet one of today's basic requirements to obtain a driver's license.[6] The GMAC Insurance National Drivers Test has become the gold standard for America's driving IQ. To test the knowledge of general driving safety rules, participants were administered a 20-question general driving test. The questions were taken from actual written Department of Motor Vehicles (DMV) tests. A balanced sample from the TNS panel, representative of U.S. individuals aged 16-65, was used for the GMAC study. In 2010, a total of 5,130 surveys were completed, with a minimum of 100 surveys per state and Washington, D.C. National data were weighted to percentage of state, age, gender, and ethnicity. National weights were applied when analyzing data on a national level to account for share of voice (i.e., California had a higher percentage in weight value due to the size of its population, while North Dakota was lower). This was only applied when analyzing data on a total level. The study measured at the 95% confidence level. [GMAC Insurance (2011)]

The analysis in this study utilizes annual U.S. state-level data for the years 2005 through 2010. The dependent variable DEATHRT is measured by highway deaths per billion vehicle-miles. The source for the death and vehicle-miles figures is the Federal Highway Administration [FHWA] (various years).

The independent variable INCOME (real per capita disposable income, in dollars) is based on total nominal disposable income values from the Bureau of Economic Analysis (2011), population figures from the U.S. Census Bureau (2011 and 2014), and values of the Consumer Price Index for all urban consumers (base period: 1982-84) [Bureau of Labor Statistics (2014)]. FHWA (various years) is the data source for the explanatory variable RURURB (rural vehicle-miles divided by urban vehicle-miles). Information for the weather variables TEMP (annual mean temperature, in degrees Fahrenheit) and PRECIP (annual precipitation, in inches) comes from the National Climate Data Center (2011).

FHWA (various years) is the data source for the driver characteristics YOUNG (percentage of licensed drivers aged 24 years or younger) and OLD (percentage of licensed drivers aged 65 years or older). Values for ALCOHOL (per capita apparent alcohol consumption, in gallons) for 2005-09 come from the National Institute on Alcohol Abuse and Alcoholism [NIAAA] (2011) and for 2010 come from NIAAA (2014).[7] The sources for information on SBELTUSE (seat belt use rate) for 2005-09 and 2010 are NHTSA (2010) and NHTSA (2011), respectively. Figures for the driving knowledge variables—TESTAVG and TESTRANK—are as reported by GMAC Insurance (2011). TESTAVG is the average percentage score on the GMAC Insurance National Drivers Test for test takers from a particular state. TESTRANK is the numerical position of a particular state's TESTAVG value in a descending-order ranking of all state TESTAVG values.

To account for spatial considerations, dummy variables are included for the nine Census Divisions: New England (NEWENGL), Middle Atlantic (MDATLAN), East North Central (ENOCNTRL), West North Central (WNOCNTRL), South Atlantic (SOATLAN), East South Central (ESOCNTRL), West South Central (WSOCNTRL), Mountain (MOUNTAIN), and Pacific (PACIFIC). The U.S. Census Bureau (2010) is the source for this information. A linear trend variable (TREND) controls for temporal effects. Table 1 provides summary statistics on the variables used in the model estimations.

Table 1: Summary Statistics of Variables

Variable	Mean	Standard Deviation
DEATHRT	13.477	3.907
INCOME	16,118.77	2,105.018
RURURB	0.959	0.789
TEMP	52.864	7.535
PRECIP	37.750	15.102
YOUNG	13.505	1.957
OLD	15.751	1.834
ALCOHOL	2.375	0.470
SBELTUSE	83.150	8.059
TESTAVG	79.592	3.928
TESTRANK	25.196	14.328
NEWENGL	0.122	0.328
MDATLAN	0.063	0.243
ENOCNTRL	0.105	0.307
WNOCNTRL	0.147	0.355
SOATLAN	0.168	0.374
ESOCNTRL	0.084	0.278
WSOCNTRL	0.084	0.278
MOUNTAIN	0.164	0.371
PACIFIC	0.063	0.243
TREND	3.517	1.704

ESTIMATION RESULTS

Table 2 contains the regression estimation results for four different models. In each model the dependent variable is DEATHRT. Models 1 and 2 have linear functional forms, and Models 3 and 4 have log-log specifications.[8] Except for the measures for driving knowledge, the independent variables are the same in all models. In Models 1 and 3, driving knowledge is measured by the state's test average (TESTAVG), while in Models 2 and 4 it is approximated by the state's ranking

Table 2: U.S. State-Level Regression Estimates of Motor Vehicle Deaths per Vehicle-Mile, 2005–2010

Independent Variable	Expected Sign	Dependent Variable: DEATHRT			
		Model 1	Model 2	Model 3	Model 4
Intercept	?	6.463	0.836	3.867[bb]	2.035
		(1.388)	(0.260)	(2.443)	(1.607)
INCOME	?	-3.56E-04[bb]	-3.60E-04[bb]	-0.331[bb]	-0.332[bb]
		(-5.361)	(-5.482)	(-3.638)	(-3.652)
RURURB	+	1.840[aa]	1.901[aa]	0.141[aa]	0.139[aa]
		(9.721)	(10.046)	(9.710)	(9.734)
TEMP	+	0.188[aa]	0.173[aa]	0.852[aa]	0.825[aa]
		(7.747)	(6.906)	(8.941)	(8.467)
PRECIP	-	-0.001	-1.65E-04	-0.061[aa]	-0.059[aa]
		(-0.108)	(-0.013)	(-1.974)	(-1.906)
YOUNG	?	-0.005	0.009	0.118	0.129[b]
		(-0.067)	(0.138)	(1.634)	(1.772)
OLD	?	0.501[bb]	0.507[bb]	0.616[bb]	0.623[bb]
		(7.088)	(7.243)	(8.240)	(8.302)
ALCOHOL	+	1.247[aa]	1.267[aa]	0.226[aa]	0.228[aa]
		(5.004)	(5.131)	(4.887)	(4.931)
SBELTUSE	?	-0.077[bb]	-0.074[bb]	-0.352[bb]	-0.361[bb]
		(-4.871)	(-4.690)	(-3.911)	(-4.021)
TESTAVG	-	-0.057[a]		-0.420[aa]	
		(-1.409)		(-1.808)	
TESTRANK	+		0.029[aa]		0.021[aa]
			(2.707)		(1.890)
MDATLAN	?	3.644[bb]	3.573[bb]	0.225[bb]	0.235[bb]
		(6.960)	(6.904)	(6.200)	(6.583)
ENOCNTRL	?	2.724[bb]	3.027[bb]	0.104[bb]	0.106[bb]
		(5.199)	(5.665)	(3.021)	(3.057)
WNOCNTRL	?	3.306[bb]	3.754[bb]	0.134[bb]	0.142[bb]
		(5.968)	(6.469)	(3.442)	(3.542)
SOATLAN	?	4.460[bb]	4.692[bb]	0.248[bb]	0.252[bb]
		(8.958)	(9.337)	(6.894)	(6.957)
ESOCNTRL	?	5.490[bb]	5.742[bb]	0.288[bb]	0.291[bb]
		(9.381)	(9.739)	(6.655)	(6.711)
WSOCNTRL	?	5.270[bb]	5.620[bb]	0.262[bb]	0.266[bb]
		(8.305	(8.701)	(5.667)	(5.729)
MOUNTAIN	?	6.459[bb]	6.814[bb]	0.355[bb]	0.361[bb]
		(9.510)	(9.907)	(6.765)	(6.792)

(Table 2: continued)

Independent Variable	Expected Sign	Dependent Variable: DEATHRT			
		Model 1	Model 2	Model 3	Model 4
PACIFIC	?	4.662[bb]	5.126[bb]	0.240[bb]	0.256[bb]
		(6.951)	(7.4190)	(5.291)	(5.310)
TREND	?	-0.777[bb]	-0.704[bb]	-0.059[bb]	-0.052[bb]
		(-9.072)	(-11.540)	(-9.761)	(-12.108)
N		286	286	286	286
R^2		0.843	0.846	0.862	0.862
Adjusted R^2		0.833	0.836	0.853	0.853

Notes: t statistics are in parentheses. In Models 3 and 4, all variables except the Census Division dummies and TREND are in natural logarithms. The control category for the Census Divisions is New England (NEWENGL).

[a] significant at .10 level (one-tail test)
[aa] significant at .05 level (one-tail test)
[b] significant at .10 level (two-tail test)
[bb] significant at .05 level (two-tail test)

across all states (TESTRANK). Based on the R^2 statistics reported in Table 2, all four models explain more than 80% of the variation in the motor vehicle death rate.

INCOME is statistically significant and negatively related to DEATHRT in all four models.[9] These results suggest that better economic conditions increase the demand for safety, and fewer fatalities result. This corroborates findings based on pooled cross-section, time-series data as summarized in Loeb, Talley, and Zlatoper (1994, pp. 18-19).

Where a person drives influences DEATHRT. In all four models, there is statistically significant evidence that as the ratio of rural to urban driving increases, so does the fatality rate. Rural driving conditions may involve less congested roads (higher speeds) as well as different types of road conditions. Also, rural settings may offer fewer nearby medical options in the event of an accident and consequently increase the chance of a fatality.

Higher temperatures, and presumably better driving conditions, are positively related to highway fatalities. More precipitation, however, reduces the death rate. Both weather variables may influence the driver's level of attention as well as vehicle speed. The signs for both weather variables are as anticipated, with TEMP significant across all four models and PRECIP statistically related in the log-log models.

The age of the driving population is related to the death rate. A younger driving population generally increases the fatality rate. YOUNG's coefficient is positive in all but Model 1 and is statistically significant in Model 4. There is stronger evidence that older drivers contribute to a higher death rate. The coefficient of OLD is positive and statistically significant in all four models.

Alcohol-impaired motorists create hazardous driving conditions and contribute to motor vehicle fatalities. All four models reveal a statistically significant relationship between alcohol consumption and the death rate. Following conventional wisdom, the estimated coefficients are positive. This aligns with the findings of a large body of previous research on the impact of alcohol on highway safety.

In this analysis seat belt use is found to have a live-saving effect. Across all four models, the coefficient of SBELTUSE is negative and statistically significant. This corroborates previous research findings by NHTSA.

Regardless of the measure used, results suggest that greater knowledge of general highway safety rules enhances highway safety. As expected, the average test score (TESTAVG) coefficients are negative in Models 1 and 3; and the test rank (TESTRANK) coefficients are positive in Models 2 and 4. All of these results are statistically significant.

The control category for the Census Division dummy variables is New England (NEWENGL), so the results for these geographic variables are evaluated in comparison to this omitted division. In all four models, the coefficients for all of the Census Division dummies are positive and statistically significant. This suggests that in the geographic areas included in the estimated models there are factors leading to higher fatality rates than in New England.

The coefficient of TREND is negative and statistically significant in all four models. This implies that there are influences not explicitly controlled for in the estimations that contributed to a decline in the highway death rate over the period analyzed. For example, the trend variable may be capturing improved safety technology built into the driving fleet over time.

SUMMARY AND IMPLICATIONS

This paper is an effort to better understand the factors that influence motor vehicle deaths across U.S. states and over time. One contribution is the addition of driving knowledge, as measured by a written driver's test, to a set of factors consistent with contributory factors to explain deaths per vehicle-mile. Four models, estimated using annual U.S. state-level data over six years (2005 through 2010), provide results generally consistent with previous findings. The estimations use two functional forms: linear and log-log.

Estimation results pertaining to the influences of several explanatory factors are robust across the models that include them. Negatively related to the fatality rate and statistically significant are: real per capita income, precipitation, seat belt use, and a linear trend. The models also reveal statistically significant positive associations with the highway death rate for the ratio of rural to urban driving, temperature, the percentage of young drivers, the percentage of old drivers, and alcohol consumption. Census Division dummy variables add statistically significant explanatory power and reveal death rate differences across geographic regions.

While common perception suggests more knowledge leads to better road safety, earlier empirical support—using a written driver's test as a knowledge measure—was equivocal. This analysis uses two alternative measures of driving knowledge: individual state average and the ranking on the GMAC Insurance National Drivers Test. Data examining all 50 states strongly support the safety effects—as measured by lower death rates—of the written driving test. Regardless of the measure used, driving knowledge exhibits a statistically significant life-saving effect.

A number of implications follow this result. Lack of critical safety comprehension increases the risk of accidents or near accidents. Lowering this risk is likely to reduce both accidents and costs of insurance premiums. Further, increased overall safety is a public good. Finally, greater emphasis on the written test naturally complements the recent emphasis on the GDL programs to produce a better population of novice drivers.

Acknowledgements

An earlier version of this paper was presented at the Eastern Economic Association Meetings in Boston, Massachusetts, on March 8, 2014. The authors thank Dr. Michael W. Babcock, co-general editor, and two anonymous referees for several helpful suggestions and assume responsibility for any remaining errors.

Endnotes

1. Driving knowledge as referred to in this paper focuses on the understanding of driving rules as typically measured by a written driving test.

2. Previous research found that altitude and alcohol consumption have an interactive effect on highway safety. See Loeb, Talley, and Zlatoper (1994, p. 35).

3. According to Peltzman (1975, p. 681), a driver faces a tradeoff between safety and "driving intensity." A reduction in the former (i.e., a higher probability of death from accident) results from an increase in the latter (e.g., greater speed, thrills, etc.).

4. Seat belt use may lead to riskier driving. This may result in harmful consequences for non-occupants.

5. The values for TESTRANK are 1 for the highest ranking state, 2 for the second highest, and so on. Thus, a higher rank corresponds to a lower value on this variable.

6. GMAC Insurance survey data for 2011 are not included in the data set of this study because data for other variables was unavailable.

7. Data on alcoholic intoxication while driving are unavailable. Therefore, information on this activity for the population in general is utilized in this analysis. The assumption is made here that the behavior of drivers with regard to this activity is highly correlated with that in the general population.

8. In Models 3 and 4, all variables except the Census Division dummies and TREND are in natural logarithms.

9. In this paper "statistically significant" refers to significance at a level of .10 or less.

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