Assessing the Determinants of Safety in the Trucking Industry

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ABSTRACT

Using data from the 1997 Survey of Drivers conducted by the University of Michigan Trucking Industry Program, we identify the factors which substantially affect three safety measures: accidents, moving violations, and hours of service violations. The variables used include both operational characteristics (firm size, trailer type) and personal characteristics (age, race, union status). Using both basic descriptive statistics and probit estimation, we find that the variables that have the most impact on the three safety measures are operational in nature, not individual characteristics.

INTRODUCTION

There can be little doubt that safety in the trucking industry is one of the most contentious issues in transportation. With headlines that read, "America's Most Dangerous?" and "They Drive by Night," articles on trucking safety appear more and more frequently in the popular press. One recent example appeared in the *Denver Post* titled "Truck Crashes Claim Thousands: Safety Agency Ripped for Shoddy Oversight" (Alonso-Saldivar 1999) with a passage that read, "Spewing gravel

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on windshields and careening across crowded freeway lanes, trucks are the staple of local news video of chain-reaction death on the highway."

Up from 4,755 in 1996, the number of trucks involved in fatal accidents, the most often-cited measure of safety, was 4,871 in 1997, with the total number of fatalities stemming from these accidents at 5,355. However, more trucks were involved in driving more miles in 1997 than in 1996. The rate of fatal accidents was 2.5 per 100 million miles traveled in 1997, down from 2.6 the year before (Schulz 1998c).

Truck accidents are much less likely than passenger car accidents to involve illegal alcohol content: 1.4% versus 19.4% (Schulz 1998b). Though there has been concern in the past with drug use by truck drivers, especially amphetamines, in 1996 less than 0.2% of truck drivers tested positive for drug use.The purpose of this paper is to assess the characteristics which influence driver safety. To this end, we employ data obtained by the University of Michigan Trucking Industry Program in its 1997 Survey of Drivers.[1] These data have the advantage of being comprehensive since they include questions on individual and firm characteristics, hours of service regulations, and safety, and of having been collected from a nongovernmental source, perhaps ensuring more confidence from the drivers and thus more reliable and honest responses to sensitive questions.

[1] The data are from a survey of over-the-road and local drivers in the motor freight industry conducted by the University of Michigan Trucking Industry Program (UMTIP) in the late summer and fall of 1997. The survey used a two-stage, stratified sampling procedure in which interview sites, truck stops, were randomly selected within state and establishment size categories. Interviewers approached entrants to the selected truck stops using a random selection scheme. Sixty-three percent of eligible participants, 573 drivers, agreed to take the survey, which took forty minutes. The survey collected information on topics including respondents' work history; the characteristics of their job and the structure of compensation on the job; time spent working, waiting and resting in the last 24 hours and on the last completed trip; the use of technology; respondents' characteristics, education, and job training; their use and attitudes toward log books and the hours of service regulations; and their views about the current employer and unions.

Using these data, we first use descriptive statistics to assess the factors, both operational and personal, which influence driver safety. We then employ probit estimation techniques to assess what impact the significant variables have on driver safety, all else remaining constant. Our results indicate that variables such as hours of sleep and miles driven, as well as method and rate of pay, play major roles in driver safety.

RELEVANT LITERATURE

There were 151,000 trucks involved in traffic accidents in the United States in 1994, resulting in 5,501 fatalities and 110,000 nonfatal injuries (Center for National Truck Statistics 1996). The 1996 fatality rate for commercial motor vehicles was 2.8 per million miles traveled, versus 2.0 per million miles traveled for passenger cars (Schulz 1998b).

Many studies have attempted to explain the factors in these accidents and the relative likelihood that a commercial motor vehicle will be involved in a traffic accident. Explanatory variables used include, among others, driver fatigue, driver hours of service, driver age and experience, driving conditions, driving under the influence of alcohol, and deregulation of the trucking industry. Human error is cited more often than mechanical defects in truck-related fatalities, emphasizing the need to study variables such as and similar to the aforementioned (Schulz 1998b).

Perhaps the most visible safety hazard in the trucking industry is driver fatigue. At the 1995 National Truck and Bus Safety Summit, driver fatigue was identified as the leading safety issue in the industry (USDOT FHWA 1998). The National Transportation Safety Board estimated 31% of all truck-driver fatalities and 58% of all single-truck crashes are fatigue related (Schulz 1998a).

According to the NASA/Ames Fatigue Countermeasures Group, fatigue is caused by two physiological phenomena: sleep loss and circadian rhythm disruption. As little as two hours of sleep loss, which over several days can accumulate into a "sleep debt," can negatively affect performance and alertness. The disruption of circadian rhythms occurs with schedule changes, such as crossing time zones or shift changes. Truck drivers, especially long-haul drivers, are unusually vulnerable to both types of fatigue.

In 1988, Congress directed the Federal Highway Administration to study driver fatigue and its implications with respect to the hours of service rules. The FHWA concluded in the "Commercial Motor Vehicle Driver Fatigue and Alertness Study"(USDOT FHWA 1996) that "drivers in the study did not get enough sleep" and "were not very good at assessing their own levels of alertness." A publication in the *New England Journal of Medicine* (Mitler et al. 1997) presents the results of electrophysiologic and performance monitoring of drivers. The drivers averaged only 4.78 hours of electrophysiologically verified sleep per day. Forty-five of the drivers (56%) had a least 1 six-minute interval of drowsiness while driving, and 2 drivers had 1 episode each of stage 1 sleep (the lightest stage of sleep) while driving.

The hours of service rules were implemented in the 1930s to protect drivers from being forced to work long and unsafe hours and have changed little since that time. These rules prescribe the maximum hours that a driver may spend on-duty or driving. On-duty time includes all time that the driver is responsible for the truck, including passive activities such as waiting to load or unload. Ten hours of driving is permitted after 8 consecutive hours off-duty, and driving is not permitted after 15 hours on-duty. During any seven-day period, a maximum of 60 hours of driving is permitted. Or, a maximum of 70 hours of driving is permitted during any eight-day period.

Braver et al. (1992) present the results of a study in which 1,249 tractor trailer drivers were interviewed at various locations in Connecticut, Florida, Oklahoma, and Oregon about their usual hours of work and driving. They found that 73% of the drivers were classified as hours of service violators. Significant risk factors for being a violator included the following: low pay rates per mile, high annual miles driven, employment with a for-hire firm, irregular route schedules, having received an unrealistic delivery deadline within the past month, carrying a perishable commodity, and frequent difficulties finding parking in rest areas or truck stops.

Beilock (1995) reports the results of a survey of 500 drivers exiting the Florida peninsula on January 25 and 26, 1998. Depending on average speeds, between 17% and 30% of the drivers surveyed had violation-suspect schedules; between 14% and 26% of the schedules were judged as violation-inducing. Factors that contributed to a tight schedule included the following: solo driving, full loads, refrigerated loads, regular-route schedules, and current trip lengths over 1,000 miles.

Kaneko and Jovanis (1992) developed a method to estimate the relative accident risk or different driving patterns over a multiday period. Nine distinct driving patterns were identified from a data set of over 1,000 drivers. Additional models Kaneko and Jovanis developed considered the driver's age, the driver's experience with the employing firm, the driver's number of hours off-duty prior to the last trip, and the hours driving on the last trip. They concluded that, with marginal statistical significance, early and late morning driving over multiple days was associated with the highest accident risk. Driver age and the number of hours off-duty immediately prior to a trip did not appear to significantly affect accident risk, but driver experience and the number of consecutive hours driven were significant. Drivers with one to five years of experience comprised the highest risk group, while drivers with less than one year of experience comprised the second highest risk group. The lowest risk associated with the number of consecutive hours driven was during the first four hours, and the highest risk was beyond nine hours driven.

Jones and Stein (1987) conducted a case-control study of crashes in the state of Washington from June 1984 to July 1986. They concluded that drivers who drive in excess of hours of service regulations, young drivers, and interstate drivers were likely to have an increased relative risk of crash involvement.

Traynor and McCarthy (1993), using data from California, examined whether the Motor Carrier Act of 1980, which deregulated the trucking industry, affected the probability that a truck would be involved in an accident or that a truck would be at fault in an accident. They concluded that economic deregulation, which essentially allowed the trucking industry to become nearly perfectly competitive, had a "statistically insignificant (positive) effect on highway safety." Alexander (1992) determined that Traynor and McCarthy's conclusion about deregulation in California was not different from what occurred in other states.

DESCRIPTIVE STATISTICS

Using the findings of previous studies as a foundation and incorporating some of our own hypotheses on the factors which may play a significant role in driver safety, we generated descriptive statistics using the UMTIP 1997 data sets, and these factors were related to three safety measures. The three safety measures are: first, whether the driver reported having been involved in an accident reported to the police while on duty in the 12 months prior to the interview (this includes all accidents, not the subset of fatal accidents); second, whether the driver had been cited for a moving violation while on duty in the 12 months prior to the interview; and, third, whether the driver had reported working more than he/she had logged in the last 30 days. All of these are binary variables that take a value of one if the respondent replied in the affirmative to any of the questions and zero otherwise. In the sample, 15.01% reported that they had been involved in an accident; 29.87% reported having received a moving violation; and 57.8% reported having worked more than was logged in the last 30 days.[2] (Interestingly, 82.58% of all drivers reported that, in general, they thought logbooks were inaccurate.) The relatively high rates of affirmative response for each of the three safety measures lead us to believe that any underreporting due to the sensitive nature of the questions is rather low.

Descriptive statistics were compiled on driver characteristics such as race, age, experience, education, mileage, and sleep. Operational characteristics were also examined, including firm size, method of payment, employment status, and type of commodity hauled. Basic descriptive statistics on the sample used are presented in table 1.

[2] One might assume that these three measures are highly correlated; however, this is not the case. The simple correlation coefficient between accidents and moving violations is –0.05, 0.03 between accidents and logbook violations, and 0.14 between moving violations and logbook violations.

TABLE 1 Descriptive Statistics on the Driver Survey Sample Used for Estimation

Earnings and Miles	
1996 annual earnings	$35,758
1996 annual miles	114,269
Collective bargaining	
Union member	10.4%
Human capital	
Age	42.1 years
Occupational experience	15.3 years
Less than high school education	19.3%
High school diploma	45.8%
Vocational or technical degree	5.1%
Some college	21.0%
Associate of arts	4.2%
College degree or higher	4.7%
Race and ethnicity	
African American	9.0%
Native American	1.7%
Hispanic	2.4%
Caucasian	86.9%
Other characteristics	
Local driver	12.1%
Owner-operator	25.9%
Private carriage	18.3%
Paid by the hour	15.3%
Paid by percentage of revenue	34.2%
Firm size	
25 employees or less	21.5%
25 to 99 employees	20.4%
100 to 249 employees	14.5%
250 to 499 employees	11.3%
500 to 999 employees	10.4%
1,000 to 4,999 employees	11.7%
5,000 employees or more	3.8%
Last 24 hours	
Sleep	8.21 hours (std. dev. = 3.14)
Miles driven	404.5 miles (std. dev. = 268)
Safety characteristics	
Accident in last 12 months	15.0%
Moving violation in last 12 months	29.9%
Worked more than logged in last month	57.8%

Race

Whites reported the highest percentage of accidents (16.11%) and logbook violations (58.29%). The most interesting results of linking race to safety measures are the statistics on the subgroup of African-American drivers. African-Americans reported the lowest percentage of logbook violations (32.19%) and accidents (10.02%), but, of the three specific races, African-Americans reported the highest percentage of moving violations (35.73%).

Age

The relationship between age and safety measures is generally a U-shaped function but has significant fluctuation, as can be seen in table 2. Initially, the percentage of reported accidents and violations is high but decreases as age increases. The percentage then turns upward once again as age increases. The U-shaped function tends to hold for accidents as well. Only 10.19% of the age group 51 to 60 reported involvement in an accident in the past year, while age group 61 and older reported the highest, at 31.23%. Although the youngest group (18 to 25) did not consistently report the highest percentage of violations or accidents, the 26 to 35 group, comprising 22% of the total sample, reported the second highest percentage of accidents and moving violations (18.06% and 38.03%, respectively), and almost 70% reported violating their logbook in the past 3 months.

TABLE 2 Statistics on Safety Characteristics by Age Group

Age group (in years)	Percentage of accidents	Percentage of moving violations	Percentage of logbook violations
18 to 25	14.72	45.02	62.86
26 to 35	18.06	38.03	69.35
36 to 50	14.27	26.19	57.83
51 to 60	10.19	28.02	37.26
61 and older	31.23	28.55	44.57

Firm Size

The initial statistics indicate an inverse relationship for accidents and moving violations and firm size, as is presented in table 3. As the size of the firm increases, the percentage of reported accidents and moving violations decreases. Only 8.01% of drivers employed at firms of 500 to 999 employees, 5.45% of drivers at firms with 1,000 to 4,999 employees, and 11.11% at firms with 5,000 or more employees reported involvement in an accident in the previous year, compared with roughly 20% of drivers at firms with less than 25 or with 25 to 99 employees. Approximately 40% of drivers employed at firms with less than 25 employees reported a moving violation, compared with 8.40% of drivers employed at firms of 500 to 999 employees and 12.27% of drivers at firms with 5,000 or more employees.

TABLE 3 Statistics on Safety Characteristics by Firm Size

Firm size (in employees)	Percentage of accidents	Percentage of moving violations	Percentage of logbook violations
25 or fewer	18.81	40.36	54.47
25 to 99	20.83	34.13	55.73
100 to 249	16.18	24.72	61.74
250 to 499	15.09	31.38	59.47
500 to 999	8.01	12.87	68.19
1,000 to 4,999	5.45	21.82	37.59
5,000 or more	11.11	12.27	27.62

For most categories of firm size, about one half of the respondents reported violating their logbook. At the high end, 68% of the drivers employed at firms with 500 to 999 employees reported violating their logbooks, even though they reported at or near the lowest percentile for accidents and moving violations. The figures drop markedly for the largest firms, with 37.6% of drivers at firms with 1,000 to 4,999 employees and 27.6% of drivers at firms with 5,000 or more employees reporting logbook violations in the last 30 days.

TABLE 4 Statistics on Safety Characteristics by Occupational Experience

Occupational experience (in years)	Percentage of accidents	Percentage of moving violations	Percentage of logbook violations
1	27.55	36.52	15.30
2	8.03	39.20	59.73
3	20.54	23.64	68.37
4 to 5	13.35	23.35	74.06
6 to 8	10.48	28.77	53.08
9 to 12	12.45	47.51	75.33
13 to 15	13.10	19.40	55.52
16 or more	16.48	27.91	48.71

Occupational Experience

Experience seems to have a positive effect on the safety measures but is undoubtedly skewed somewhat because of its high correlation with age. As table 4 indicates, drivers with 1 year of experience reported the highest percentage of accidents, at almost 28%. As the drivers gain experience, the accident rate declines, with some fluctuation, and bottoms out around 11% for drivers with 6 to 8 years of experience. The rate then begins a slow incline to 16.48% for drivers with 16 or more years of experience.

The relationship between experience and moving violations is not as clear. With the highest percentage, nearly 48% of drivers with 9 to 12 years of experience reported a moving violation, while only 36.52% of drivers with 1 year of experience reported a moving violation. Drivers with 13 to 15 years of experience reported the lowest, at just under 20%. Those with 16 or more years reported at almost 28%.There is no clear relationship between experience and logbook violations. Around 50 to 75% of the drivers reported they had worked more than they logged in the last 30 days, with one exception. Only 15.30% of the drivers with less than 1 year of experience reported violating their logbook in the last 30 days.

Method of Payment

Drivers paid by percentage of revenue reported a higher percentage of accidents, moving violations, and logbook violations (18%, 38%, and 63%, respectively) than those paid by the mile (13%, 27%, and 55%, respectively). This is not surprising because a driver who is paid by the mile typically gets paid the same amount per mile regardless of the revenue generated by the load (exceptions being premiums paid for hazardous materials, etc.). Drivers who are paid a percentage of revenue, primarily owner-operators, tend to drive more miles and run more loads in order to compensate for any empty or low-revenue loads.

Owner-Operators versus Employees

The rates of accidents and logbook violations are remarkably similar across employment status, with roughly 15% of those in each group reporting an accident in the 12 months prior to the interview and nearly 60% of drivers in each group reporting that they had worked more than they logged in the last 30 days. Moving violations, however, varied across employment status, with 38% of owner-operators reporting a moving violation in the last 12 months versus 30% for employee drivers.

When comparing those in the for-hire segment to drivers in the private carriage segment, we find that safety characteristics are again similar. Approximately 55% of drivers in each group admit to violating the hours of service regulation in the past 30 days, and roughly 30% report receiving a moving violation in the last year. The accident rate, however, varies significantly between the groups, with private carriage drivers (23%) more likely than for-hire drivers (13%) to have been involved in an accident in the past year.

Van Type

It is indicated that drivers pulling a drybox are somewhat safer than drivers with other trailer configurations. There is little difference between drybox and other trailer configurations for accidents and moving violations, but there is a large discrepancy for logbook violations within the past 30 days. For all trailer configurations, around 15% of drivers reported an accident within the past year, while roughly 30% reported a moving violation. As for logbook violations within the past 30 days, just under 50% of drybox drivers reported violating their logbook, while 63% of drivers of other trailer configurations reported the same violation.

Annual Mileage

It is not surprising that as annual miles driven increases, so does the percentage of reported accidents, moving violations, and logbook violations. Of those drivers reporting 50,000 miles or less driven in the past year, 10% reported being involved in an accident; 20% received a moving violation; and 35% reported violating their logbooks. These figures increase as annual mileage increases and are 20%, 30%, and 67%, respectively, for those drivers reporting over 160,000 miles in the last year. This positive relationship is expected since it is likely that those driving more miles are violating hours of service regulations and, therefore, are more likely to be involved in an accident or receive a moving violation. The more miles driven, the more likely a driver is to be cited for a moving violation, and the more hours they have to falsify their logbooks to make up for the obtainable, but probably illegal, miles driven. It may well be noted, however, that the percentage involved in accidents increases with miles driven at a decreasing rate, which may indicate that those drivers who drive more miles may be safer when compared on a per-mile basis.

Sleep in the Last 24 Hours

To examine preliminarily the effect of sleep on safety, we considered our three safety measures across hours of sleep in the last 24 hours. This is a rough proxy for sleep patterns, since sleep in the past 24 hours may have been atypical of usual sleep patterns, but the results are interesting from a fatigue perspective.

Not surprisingly, those who report zero hours of sleep in the last 24 hours are most likely to have also reported an accident in the past year (28% versus roughly 15% for the rest of the sample). These drivers are also most likely to have violated the hours of service regulation in the last 30 days; 68% of those with no sleep reported logbook violations, as did 93% of those with 5.5 hours or less. These figures are significantly higher than the average of 50% for the rest of the driver sample.

Education

The pattern of the relationship between education and safety is seemingly contradictory. College graduates stand out from the other education categories. This group is by far the most likely to violate the hours of service regulations (84% versus roughly 55% for the rest of the sample) and is also the most likely to have reported an accident in the past year (22%). However, this group is the least likely to have received a moving violation (17% versus 30% for the remainder of the sample).

THE MODEL

A regression model is used to explain the rates of accident, moving violation, and logbook violations. A probit model specifically is used because of the dichotomous nature of the response variables.[3] A driver either has an accident or moving violation or logbook violation or not; the factors which affect the probability of these events occurring are what is of interest. The probit model allows us to estimate the effects of key variables while holding all other variables constant. The coefficients presented are the derivatives of the probit function evaluated at the mean, allowing us to interpret the coefficients as "marginal effects."

Three separate models were estimated using identical explanatory variables and a dependent response variable of accident, moving violation, or logbook violation. The explanatory variables include dummy or continuous variables of basic demographic variables and industry related variables. The variables include gender, education level, race, ethnicity, veteran status, union status, marital status, job tenure, occupational experience and its square, driver training, trailer configuration, mileage in the last 24 hours, sleep in the last 24 hours, and a calculated mileage pay rate.[4] The explanatory variables differ somewhat from the variables viewed in the initial descriptive statistics.

First, education is split into four categories: less than high school, high school graduates, those with degrees from vocational or technical schools or associate's degrees, and those who completed some or all of college. High school is the omitted reference group in the model, since most drivers reported a high school degree as their terminal education.

Continuous variables for occupational experience and its square are included and age omitted because of the high correlation between the variables. Occupational experience and its square are desired to reflect the possibility of a learning curve that may increase at a decreasing rate. As experience increases, the probability of the three events occurring is likely to decrease but only to a certain point, at which other factors may have greater influence on safety.

Experience is a strong determinant in driver safety, but the next logical step is to question the method of driver training. Will a driver who goes through weeks of classroom and on-the-road training be a safer driver than one who learns "on-the-job," all

[3] The choice of a probit model over logit is somewhat arbitrary, however, assuming a normal distribution over a logistic distribution affects estimates little in our model. According to Greene (1997), we would expect very different predictions from the two models if there were very few responses or non-responses in the data set or if there were a wide variation in a key explanatory variable. Neither of these applies to our data set. Logit estimates are available from the authors.

[4] Correlation coefficients indicate little problem with multicollinearity in the model. A full set of correlation coefficients is available from the authors.

else being equal? Dummy variables for different types of training were included, with on-the-job omitted as the reference group. The included dummies are private school, public or technical school, courses offered by a trucking company, the military, or other (mainly learned from family or friends).

Different trailer configurations often present different schedules that drivers must abide by, thereby creating an indirect safety variable via this schedule variance. For example, a driver hauling livestock or a tanker of milk in August is more likely to be constrained by a strict delivery schedule than a driver pulling pallets of salt in a drybox. Drybox is the configuration taking a value of one for this variable, with all other configurations at zero.

Continuous variables for mileage and sleep in the last 24 hours are included to capture a driver's "normal" driving habits. A driver may report mileage or hours different from his or her norm, but it is assumed that drivers' pictures of the last 24 hours represent, on average, a typical scenario. These are important variables because of the inherent connection with hours of service laws and implied industry values toward sleep and safety. Miles in the last 24 hours may provide a good illustration of an individual's driving pattern. For example, 2 drivers with the same annual mileage, say 110,000 miles, may have very different driving patterns, with 1 driving a regular schedule and never exceeding hours of service regulations and the other regularly exceeding limits on driving time either due to company pressures or his or her own preferences.

Annual income and annual miles are dropped in favor of a continuous, computed variable of the ratio of annual income to annual miles. The computed form is favorable because it avoids a correlation problem between income and mileage and allows for comparison across different methods of compensation. The calculated mileage rate also accounts for pay for nondriving time. A dummy variable for method of payment is included, taking a value of one if the driver is paid by the hour and zero otherwise. We would expect those paid by the hour to be more likely to be regional or local drivers or to be those drivers working in the "better" trucking jobs with better working conditions. Therefore, the coefficient on this variable is expected to be negative in each of the models.

Additionally, controls are included for type of commodity hauled. This provides a more detailed distinction between for-hire and private carriage drivers. The omitted group is general freight, typically characterized as "for-hire."[5]

Finally, regional dummies are included in the model for accidents. Drivers report that driving conditions are more hazardous in some parts of the country, so the region where the driver typically works may play a role in the probability of having been involved in an accident, making region an important control variable. The omitted group is Upper-Midwest, and we would expect the coefficients on the dummies for Northeast and Mid-Atlantic (the East coast states) to be positive in this model.

Results

Accident Probit

Table 5 summarizes the results of the probit estimation. The statistically significant variables in the accident model are pay rate and method of payment, marital status, firm size, region, and source of training. The coefficient on the mileage rate variable is –0.176, indicating that a $0.10 increase in the rate paid per mile would decrease the probability of being involved in an accident by 1.76%. Likewise, the coefficient on the dummy variable for hourly pay is negative and significant, –0.102, indicating that those drivers paid by the hour are 10.2% less likely to have been involved in an accident than those paid by the mile or by a percentage of revenue.

Also negative and statistically significant is the coefficient for the separated, widowed, or divorced group. This group is 8.9% less likely to be involved in an accident than their single counterparts, all else being equal. Those drivers who received training through a trucking company program are 14% more likely to have been involved in an accident that those who learned on-the-job.

The coefficients on firm size are negative for the larger firms but only statistically significant for firms with 1,000 to 4,999 employees. Drivers at

[5] Coefficients are not presented for these control variables; however, they are available from the authors on request.

TABLE 5 Results of Probit Estimation

Variable name	Accident model	Moving violation model	Logbook violation model
Pay characteristics			
Mileage rate	–0.176* (1.80)	–0.115 (1.06)	–0.353** (2.87)
Paid hourly	–0.102** (2.41)	–0.042 (0.55)	–0.168* (1.64)
Education			
Less than high school	0.0008 (0.02)	0.074 (1.11)	–0.014 (0.16)
Vocational/ associate's degree	–0.064 (1.07)	–0.029 (0.31)	–0.063 (0.52)
College	0.059 (1.22)	–0.027 (0.42)	0.273** (3.46)
Demographics			
African American	–0.064 (1.32)	0.046 (0.54)	–0.269** (2.66)
Hispanic and Native American	–0.063 (0.88)	0.077 (0.56)	–0.086 (0.51)
Veteran	0.007 (0.18)	–0.015 (0.28)	0.069 (0.98)
Union	0.079 (1.18)	–0.195** (2.45)	–0.041 (0.37)
Female	–0.043 (0.38)	–0.085 (0.49)	–0.374* (1.75)
Married	–0.087 (1.42)	–0.068 (0.79)	0.220** (1.96)
Separated, divorced, widowed	–0.089* (1.76)	0.057 (0.61)	0.179 (1.52)
Employee type			
Owner–operator	–0.041 (1.04)	0.102* (1.70)	0.102 (1.35)
Van type			
Drybox	–0.043 (1.14)	0.052 (0.93)	–0.179** (2.52)
Occupational experience	–0.004 (0.79)	0.002 (0.18)	0.015 (1.29)
Occupational experience—squared	0.00007 (0.59)	–0.00008 (0.39)	–0.0007** (2.48)

Variable name	Accident model	Moving violation model	Logbook violation model
Firm size (in employees)			
25	0.028 (0.57)	–0.087 (1.34)	–0.013 (0.14)
100	–0.004 (0.07)	–0.123 (1.67)	0.110 (1.05)
250	–0.007 (0.11)	–0.050 (0.59)	0.059 (0.54)
500	–0.038 (0.66)	–0.254** (3.53)	0.271** (2.57)
1,000	–0.110** (2.47)	–0.127* (1.63)	–0.196* (1.68)
5,000	–0.083 (1.10)	–0.141 (1.00)	–0.204 (1.12)
Last 24 hours			
Miles	0.00003 (0.56)	0.0002* (1.82)	0.0001 (1.00)
Sleep	–0.005 (0.78)	0.007 (0.89)	–0.038** (3.16)
Source of driver training			
Private trucking school	–0.050 (1.07)	–0.151** (2.15)	0.064 (0.64)
Public or technical school	–0.089 (1.61)	0.183* (1.65)	–0.211 (1.58)
Trucking company	0.144* (1.67)	0.035 (0.34)	–0.008 (0.07)
Military	–0.032 (0.49)	0.069 (0.61)	0.107 (0.79)
Other, family member	–0.130 (0.28)	–0.065 (0.98)	–0.100 (1.11)
Diagnostics on model			
Likelihood ratio (p–value)	77.07 (0.014)	85.38 (0.0003)	126.4 (0.000)
Pseudo R^2	0.22	0.17	0.25

*significant at 10% level ** significant at 5% level

this size firm are 11% less likely to be involved in an accident than those drivers employed at the smallest firms, those with less than 25 employees.

Finally, two regions had statistically significant coefficients in the accidents model. Those drivers who typically work in the Northeast are nearly 56% more likely to be involved in an accident than those working in the Upper Midwest. Those working in the Mid-Atlantic states are 21% more likely than their Midwest counterparts to be involved in an accident. These findings support the assumptions made a priori.

It was expected that sleep in the last 24 hours and trailer configuration would significantly affect the probability of reporting an accident. It is likely that these variables and others were not significant because drivers were asked to report only if they had an accident within the last year. Also, "close calls," or nonreported accidents, are excluded. These important safety measures are, unfortunately, impossible to incorporate.

Moving Violation Probit

Union membership, firm size, owner-operator status, mileage in the last 24 hours, and training at a private trucking school or a public/technical school significantly affect the probability of a driver reporting a moving violation. Union employees are nearly 20% less likely to have received a moving violations than nonunion drivers. This is not surprising since union drivers typically experience better working conditions and are paid for all of their time, which makes driving at excessive speeds less necessary.

Owner-operators are 10% more likely to receive a moving violation than employee drivers. Also playing a positive and statistically significant role is miles in the last 24 hours, with a coefficient of 0.00017. This implies that driving an additional 100 miles in a 24-hour period increases the probability of receiving a moving violation by 2%.

Again, the coefficients on the larger firm sizes are negative and statistically significant. Drivers at firms with 500 to 999 employees are 25% less likely to receive a moving violation, and those at firms with 1,000 to 4,999 employees are 13% less likely to receive a moving violation than those drivers at firms with less than 25 employees. Those drivers who learned to drive a truck from a private trucking school are 15% less likely to receive a moving violation, and those who learned at a public or technical school are 18% more likely to receive a moving violation than those drivers who learned on-the-job.

Logbook Violation Probit

Greater amounts of sleep in the last 24 hours, hauling a drybox, higher mileage rates, pay by the hour, and being Black or female decrease the probability of reporting a logbook violation. Drivers who graduated from college or have some college are more likely than high school graduates to violate their logbook, and married drivers are more likely to violate their logbooks than their single counterparts.

Mileage rates and method of pay play a statistically significant role in driver safety when it comes to hours of service violations. Those drivers paid by the hour are nearly 17% less likely to violate their logbooks. The coefficient on mileage rate is –0.35, indicating that a \$0.10 increase in the mileage rate decreases the probability of violating the logbook by 3.5%. Blacks are 27% less likely to report working more than they logged in the last 30 days than Whites, all else being equal. Females are also less likely to report violating their logbooks: 37% less likely than male drivers.

Firm size again plays a statistically significant role, though this is not as straightforward as the previous two models. Those drivers at firms with 500 to 999 employees are 27% more likely to violate their logbooks than drivers at the smallest firms. However, drivers at firms sized 1,000 to 4,999 are nearly 20% less likely to violate their logbooks. It should be noted that the coefficients on the largest firms (5,000 or more) are negative, and those at medium sized firms are positive, though not significant. Thus, it appears that drivers at the largest of the large firms are less likely to violate hours of service regulations (or less likely to admit doing so).

Drivers pulling a drybox rather than any other trailer configuration are 18% less likely to violate their logbooks. This is most likely because of the time constraint associated with perishables and other schedule-sensitive trailer configurations. Drivers who sleep more are less likely to violate their logbooks. For every increased hour of sleep, a driver is almost 4% less likely to report a logbook violation.

College graduates and drivers who have attended but not graduated from college follow the pattern first seen in the descriptive statistics. They are 27% more likely to violate their logbooks than those with a high school degree. A possible explanation is that as the education level increases, drivers become more sophisticated in manipulating their logbooks and feel more confident in their ability to successfully violate the law.

Those who are married are 22% more likely to violate their logbooks than single drivers. This may be due to those drivers being in more of a hurry to complete a dispatch and return home or due to pressures to drive more in order to increase annual earnings.

SUMMARY AND CONCLUSION

Using data on truck drivers from the 1997 University of Michigan Trucking Industry Program Survey of Drivers, we estimated the relationship between three safety measures and driver characteristics. As expected, sleep and miles driven significantly affect driver safety via moving and logbook violations. Driving 100 more miles in the last 24 hours increases the probability of receiving a moving violation by 2%, and sleeping an additional hour in a 24 hour period decreases the probability of violating the logbook by nearly 4%.

Most notably, occupational, not demographic, variables appear to be more significant determinants of safety in the trucking industry. Mileage rate and method of payment significantly affect the probability of being involved in an accident or violating a logbook. Those paid at higher effective mileage rates were less likely to be involved in an accident or violate the logbook, as were those who were paid by the hour rather than by some other pay scheme.

Also statistically significant is firm size. Those at very large firms (1,000 to 4,999 employees) were 11% less likely to be involved in an accident, 13% less likely to receive a moving violations, and 20% less likely to violate their logbooks than those at very small firms (less than 25 employees). This may indicate that the large trucking firms, long asserting their commitment to safety, are succeeding.

Although truck driving has the potential to be a dangerous job, we can see that safety could potentially be improved by changing key determinants, such as hours of sleep, miles driven, and method and rate of pay. This study is benefitted by a unique data set and should be replicated when the second wave of data (collected in 1998) is available to further determine policy prescriptions.

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