

The Effects of Trucking Firm Financial Performance on Driver Safety

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SUMMARY

Changes in the economic conditions facing the trucking industry have raised concerns about driver safety (Belzer, 2000). Recent studies have examined the relationship between firm characteristics, operational characteristics, and human capital factors and crash involvement (Corsi et al., 1984; Chow et al., 1987; Bruning, 1989; Moses and Savage, 1992; Hunter and Magnum, 1995; Corsi et al., 2002). These studies, however, have tended to examine a limited set of variables and their correlation with safety outcomes, without accounting for the complexity of relationships that influence trucking firm, driver, and crash involvement. Specific attention should be devoted to motor carrier compensation strategies and motor carrier financial performance, and the impact of these factors on operations, driver selection and training, and carrier safety outcomes, in an age of unregulated competition.

This report uses trucking firm-level information to address the paucity of multivariate analysis accounting for the safety effect of various types of truck driver compensation and firm financial performance. Using negative binomial regression models, we find that small firms with high liquidity have better safety performance. Likewise, small firms that devote a higher share of their revenues to labor expenses tend to have better safety outcomes. Although the dataset is limited in many ways, these associations suggest that small firms may be particularly sensitive to the competitive nature of the truckload sector, relying on the human capital of drivers to overcome safety challenges due to their size.

1.0 INTRODUCTION

Public policy governing transportation services that places greater emphasis on competition and a growing economy has generated significant demand for low cost freight transportation. Theory suggests that intense competition potentially could create a business environment implicitly encouraging trucking firms to engage in risky operations that lower costs, even though costs associated with vehicular accidents are expensive. Past research reports that the public health burden of large truck crashes, as measured by deaths per 100,000 people, has not improved over time (Arnold et al., 1997). In addition, compared with other occupations, truck drivers had the highest number of worker fatalities in 2002, with 80.7 percent of those deaths occurring in crashes (Lyman and Braver, 2002; U.S. Department of Labor, Bureau of Labor Statistics, 2003). With trucking operations accounting for almost one third of the total ton-miles transported, and such operations expected to grow in the future, trucking safety continues to command heightened attention from researchers and policy-makers.

Several other groups share an interest in improving the safety outcomes of trucking operations. For instance insurance companies may inadvertently subsidize high risk trucking firms by not charging them enough; trucking firms with poor safety performance records face high insurance premiums and costly litigation fees; and shippers face losses from damaged or destroyed products, as well as litigation as an involved party. The trucking companies' challenge to provide safe working conditions for drivers and other motorists, while operating a profitable business, presents researchers with the opportunity to test predictions derived from economic theory. Empirical research on trucking safety performance generally includes variables depicting driver characteristics and behavior, trucking load characteristics, vehicle characteristics and roadway conditions as safety determinants. However, relatively little empirical research has

addressed the link between motor carrier financial performance, worker compensation level, and driver selection and training to safety outcomes. Yet these factors have been prominently identified in several studies, including *Gearing Up for Safety* (Office of Technology Assessment, 1988) and in GAO's *Freight Trucking: Promising Approach for Predicting Carriers' Safety Risks* (Office of Technology Assessment, 1991). Empirical studies that do include these factors as safety determinants suggest that trucking firms' financial performance and drivers' human capital investment seem to be significantly associated with crash involvement (Chow et al., 1987; Corsi and Fanara, 1988; Bruning 1989; Moses and Savage, 1992; Hunter and Magnum, 1995; and Corsi et al., 2002).

This study improves on previous research in several ways. First, it employs a more extensive dataset that includes firm financial performance, in addition to specific non-driving compensation policies and benefits. Second, the analysis relies on count models, which capture the non-normal distribution of crash data, which in turn provides theoretical and empirical improvements over past research. Finally, whereas earlier studies predominantly focused on bivariate correlations, count models allow for testing associations between firm performance and safety, while simultaneously controlling for other relevant firm characteristics. Thus, the advantage of the empirical approach used in this study is it allows testing for several hypotheses that have been postulated in the literature. In addition the empirical modeling of trucking safety performance contributes a tool that may be useful for policy makers. As such, the proposed research builds on prior work to extend the trucking safety research literature, while it addresses urgent policy and action-oriented needs.

2.0 DETERMINANTS OF DRIVER SAFETY

Human capital theory suggests that variations in human capital across individuals and firms contribute to differences in labor force outcomes, such as productivity and safety (Becker, 1962; Becker, 1964). Within this theoretical framework, relatively high worker compensation is required to employ individuals who possess highly valued qualities. In a competitive market, higher pay would allow firms to attract and retain drivers possessing characteristics that are associated with better driver safety records. This association between driver behavior, driver pay, and driver characteristics has been tested empirically in several studies of the trucking industry. For instance, Krass (1993) detects a significant inverse relationship between wages and crash risk for the period after economic deregulation of the trucking industry¹. The combined findings of Hirsch (1993), Rodríguez et al. (2003) and Monaco and Williams (2000), support the notion that the employment of drivers with skills that command high wages helps explain the association between high wages and strong safety performance. Hirsch (1993) suggests that human capital differences among drivers may explain a substantial fraction of driver wage differences between union and non-union drivers, as the former may have greater human capital than the latter. Monaco and Williams (2000) conclude that trucking industry compensation and human capital characteristics appear to be more significant determinants of safety than are demographic variables. Other studies have also supported a connection between driver safety and human capital characteristics and driver compensation (Beilock, 1994). However, only a few studies have examined this relationship explicitly and none has focused on crash frequency.

¹ “Deregulation” in this paper refers to “economic deregulation.” Belzer (2000) argues that a distinction must be made between economic and social regulation. Although the latter – including hours-of-service and other safety regulations – have an economic impact, they are not designed primarily to regulate the economic environment but rather regulate the social consequences of economic competition.

In addition to human capital investment, other factors such as occupational demands also influence safety outcomes. Past research has examined the link between occupational factors such as working conditions and driver fatigue. Fatigue arguably is one of the most important risk factor that emerges from analyzing the role of occupational factors in driver safety (Feyer et al., 1993; Shaw et al., 2003). Most studies of fatigue have examined the causes and the extent of fatigue in truck drivers (McCartt et al., 1997; Lyznicki et al., 1998; Hakkanen and Summala, 2000) and the link between fatigue and crash risk (Hensher et al., 1992). McCartt et al. (1997, 2000) find that drivers believe that the scheduling of loads (measured as driving hours and waiting time for loads) contributes significantly to fatigued driving. Similarly, after conducting focus groups to examine the factors related to truck crashes, Chatterjee et al. (1994) conclude that direct pressure from dispatchers forces drivers to work long hours under unsafe conditions. Lin et al. (1993) rely on operational data from another large national less-than-truckload (LTL) carrier to find that total driving time has a greater effect on crash risk than either time of day or driving experience.² Hence, even if trucking companies pay high wages to attract and maintain safe drivers, poor working conditions can still lead to poor safety records.

Determinants of driver safety are not limited to driver compensation, driver attributes and occupational demands of drivers. The financial performance of trucking firms also is expected to influence safety outcomes for several reasons. This occurs if, for example, investment decisions of trucking firms were artificially constrained or if there is divergence in private and social incentives to invest in safety. When firms have additional information about their safety levels than other market participants, they may invest too much or too little than what is socially desirable and thus financial conditions would be reflected in safety outcomes. This is because

² Not surprisingly, occupational factors also have been associated with illegal substance use (Hensher and Battelino, 1990; Hensher et al. 1992) and a higher propensity to speed (Hensher et al., 1991).

trucking firms can be viewed as choosing a level of safety that balances the cost of additional safety investments with the benefits of reduced crash risk. Likewise, regulatory incentives also influence safety investments. Firms choose to comply with safety regulations based on the incremental cost of doing so, the probability of being caught without complying with the regulations, and the costs related to non-compliance.

Safety investments of a firm can include hiring drivers with higher levels of human capital, maintaining vehicles better, and complying with internal and external safety regulatory incentives. The benefits of lower crash risk for a firm include lower insurance premiums or self-insurance set-asides, higher prices, and higher reputation and quality of service. Shippers have some incentives to monitor firm safety and to penalize those firms that underinvest in safety, because this may lead to negative results for the shipper, such as unreliable delivery times and damaged goods.

The importance of financial performance as a safety determinant has heightened significance in an unregulated economic environment. In the deregulated trucking market, carriers have emphasized efficiency and low shipping costs. Efficiency gains in a labor-intensive industry such as trucking might be achieved through increased work loads. Lower shipping costs might arise from trucking firms lowering the value of worker compensation packages, and pressure to adopt these managerial practices may vary by carrier profitability. Profitable carriers have enough resources to invest in human capital and in maintenance, whereas financially distressed carriers might tend to reduce expenditures on maintenance and in other areas that affect safety or engage in operating practices that are not conducive to safety.

Indeed, theoretical and empirical models provide further insight into the links between safety investments and firm financial performance. Models of financial constraints (Fazzari,

1987; Fazzari, 1993) and decision-making nearing bankruptcy (Chen, 1995; Opler, 1994) provide theoretical examples of such connections. Empirically, the evidence in trucking shows some support for the notion that profitable carriers have safer working conditions and better safety performance than unprofitable carriers. For instance, findings by Chow *et al.* show that carriers close to bankruptcy skimp on maintenance, use older equipment, and use owner-operators (Chow et al., 1987)³. A statistically significantly positive association between trucking profitability and safety performance is reported by Corsi and Fanara (1988). They find that such significance occurs when estimating the association between operating ratio (operating expenses divided by operating revenue) and crash rates for Class I and II carriers in 1977 and 1984.⁴ However, Blevins and Chow (1998) further studied the profitability-safety relationship during the post-deregulation era using bivariate analyses, finding no statistically significant results.

In summary, there is some evidence suggesting a relationship between firm financial performance and safety. Past research also suggests that occupational demands and human capital characteristics are related to driving behaviors and crash outcomes. Given the apparent link between level of driver pay and driver safety, one expects that firms would raise pay in order to skim the cream of the trucking labor market. Since trucking deregulation, the payment of high wages occurs only in protected sectors (those with barriers to entry) and in unionized firms.⁵ Furthermore, on average, earnings of truck drivers and the quality of driving jobs continue to erode, especially among non-union drivers (Belzer, 1995; Belzer, 2000). Although speculative, two explanations may be possible: either motor carriers' post deregulation financial performance

³ Owner-operators are considered low cost alternatives to for-hire carriers.

⁴ Further research on the profitability-safety performance association for trucking firms is reported by Bruning (1989), Moses and Savage (1992, 1996), Hunter and Mangum (1995), Wilde (1995) and Corsi, Barard and Gibney (2002).

⁵ Past findings by Hirsch (1988) and Rose (1987) show declining for-hire wage rates following deregulation.

weakened such that they were limited in the pay they could provide workers, or trucking firms perceive that the benefits of higher pay did not justify the high labor costs.

Previous findings may be explained by the fact that distressed carriers can stay in business by cutting costs in motor freight operations, by running old fleets, by paying lower wages, and by requiring or providing incentives for drivers to work longer hours. Each of these approaches to cost-savings can lead to poor safety performance. Limited empirical research on safety performance links driver compensation, driver behavior and trucking firms' economic welfare. This study thus builds on prior research while recognizing that financial performance, firm operations, and human capital can be important determinants of truck driver crash involvement.

3.0 FIRM-LEVEL DATASET

3.1 Sources

Three predominant data sources reporting firm level information on trucking companies are used to examine the effect of driver compensation, occupational demands, and firm financial performance on safety. The primary data source for the firm level study is "The National Survey of Driver Wages" published by Signpost, Inc. This is a quarterly convenience survey of approximately 200 truckload firms of various sizes. These firms were chosen on the basis of the *Commercial Carrier Journal* list and other sources of top 100, second 100, and other truckload firms. Signpost also includes most of their own subscribers in the data, but there are many firms in the sample who do not subscribe to it. A caveat associated with the Signpost data set is the non-randomness of the sample selection. For instance, small carriers are most likely to be excluded from the sample. Nonetheless, most of the carriers are national, and these national carriers – in combination with some regional firms – reasonably represent the labor market.

Although Signpost was unable to provide an assessment of the randomness of the sample, the Signpost data recently were used for a compensation study conducted by the American Trucking Association Foundation⁶ and are considered by many in the industry to provide a reasonable approximation of driver pay in truckload. Signpost data were obtained for the fourth quarter of 1998. In the summer of 2000 a supplemental survey of firms identified in the Signpost data was implemented. This was due to concerns with the quality of data on non-driving compensation in the original Signpost dataset⁷.

The second source provides information on crashes, an indicator of carrier safety, reported in the Motor Carrier Management Information System (MCMIS) by the U.S. Department of Transportation (DOT). The data set includes all carriers, but suffers from the limitation of only partial reporting of carrier crashes by responsible state authorities, though incomplete reporting does not seem to vary systematically by state.

The third source of firm-level information is taken from the Motor Carrier Financial and Operating Statistics (F&OS) Program, administered by the U.S. Department of Transportation's Bureau of Labor Statistics (BTS). This information comprises over 200 fields of data collected from Class II (adjusted annual operating revenue from \$3 to \$10 million) and Class I (larger than \$10 million) motor carriers. It includes a variety of financial and operating statistics, originally collected by the Interstate Commerce Commission (ICC)⁸. The frequency of missing motor carriers and variables is a shortcoming of this data source, unfortunately. For instance, even though 10,000 firms were listed in the TTS National Motor Carrier Directory as being Class I or

⁶ The American Trucking Association Foundation is now known as the American Transportation Research Institute.

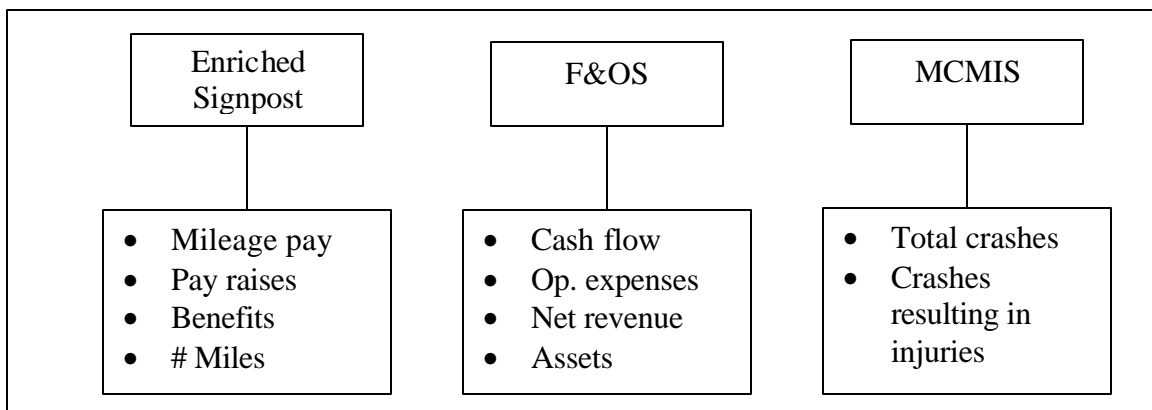
⁷ The information on compensation for non-driving work in Signpost suggests a wide degree of payment methods difficult to compress into a single measure. The original Signpost data on pay for loading and unloading is presented as either a flat rate, or an amount per hour, or one of several other modes. These data do not permit development of a more finely tuned scale of pay for loading and unloading.

⁸ See <http://www.bts.gov/mcs/desc.html>.

Class II firms with at least \$3 million in revenue, both the American Trucking Associations and Transportation Technical Service (TTS) publish F&OS data on approximately 2,000 firms only. A new program by the BTS seeks to remedy this reporting deficiency and resolve the discrepancy between the TTS data and Financial and Operating Statistics obtained by the BTS. Nevertheless, where available, Form M Data has the advantage of providing more accurate and up to date firm-level measures of fleet size, miles of operation, and other variables than is available from other sources.

Data from the enriched Signpost data, MCMIS, and from the DOT’s F&OS were merged by matching carriers listed in each survey. Additional information on the number of power units per firm for 1997 was obtained from the 1999 National Motor Carrier Directory⁹. Taken together, the resultant dataset provides a rich set of information in part because it contains financial indicators, firm characteristics, operations, and safety data. One major shortcoming of merging these datasets, however, comes from the reduced sample size obtained, which varies from approximately 60 to 102 truckload motor carriers, depending on the variables selected. Figure 1 lists the variables taken from the sources to examine truck driver safety performance.

Figure 1: Primary data sources



⁹ Signpost only provides categorical data regarding the number of power units.

3.2 Variables observed

The sample used in the analysis consists of firms with mileage-paid employee drivers responding to our supplementary survey of Signpost respondent firms. Of 178 firms that paid their employee drivers by the mile, we received valid responses from 102 firms, representing a response rate of 57 percent. Of those, we were able to successfully match 62 firms with F&OS data for 1997. When a firm did not match the F&OS, the 1998 data were used. Additionally, two firms were removed from the dataset because they were not for-hire firms, leaving a total of 60 firms in our dataset.

The dependent variable for our analysis is a firm's safety performance (CRASH), which is represented by the number of the Department of Transportation-reported crashes during 1998 for each firm. Descriptive statistics for the 60 firms listed in the merged dataset show that they had an average of 74.7 crashes (Table 1). These crashes resulted in an average of 2.4 fatalities and 35.9 injuries per firm in the observation year. Explanatory variables presented in Table 1, other than firm financial performance variables, include measures of compensation for driving (PAY), which can be viewed as proxies for unobserved human capital characteristics, uncompensated non-driving time (UNPAID), safety and compensation incentives (RAISE, SAFEBON), benefits (PAIDVAC, HEALTH, LIFEINS), exposure (MILES) and firm size (POWER UNITS)¹⁰.

¹⁰ Information in Table-1 indicates significant variation in driver compensation across trucking firms. For instance, the average starting rate of pay for a driver with three years experience was 29 cents per mile, with a minimum of 24 cents and a maximum of 37 cents per mile (PAY). The variable UNPAID, measuring the number of hours of unpaid time per mile driven, measures the amount of uncompensated time relative the paid time. The mean amount of unpaid time is 0.004 hours per mile driven. Since an average trip in this data set is about 890 miles, on average drivers worked 3.56 hours of unpaid time per trip. PAIDVAC measures the value of the sum of pay for vacation, holiday and sick time. The average firm offers about \$757.7 worth of paid time off per year, with a minimum of \$350 and a maximum of \$2,000. More than half of the firms provide a safety bonus (SAFEBON). The average driver contribution to the health plan (HEALTH) is about \$160 per year with a minimum of zero and a maximum of \$368, while the amortized value of company-paid life insurance is \$15,858 (LIFEINS).

The analysis of financial effects on safety performance focuses on three different indicators used to measure the financial welfare of the firm. Two of these ratios – operating ratio and labor cost per revenue – measure profitability. Operating ratio (OP_RATIO) is calculated as a carrier's operating expenses divided by its operating revenue. The average operating ratio of the sample of firms used in the study is 0.95, which according to Corsi et al. (2002) is indicative of a poor financial performance, but it is representative of the competitive conditions of the truckload industry sector. The labor cost per revenue ratio (LABPREV) measures the proportion of net revenue paid out in salaries and wages, which in this sample is 35%. Based on human capital theory (Becker, 1964), we hypothesize that the higher the labor cost per revenue ratio, the better the firm safety performance, *ceteris paribus*.

The third financial welfare measure reported in the data set is cash flow ratio (CF_RATIO). Defined as the cash flow from operations divided by current liabilities, the cash flow ratio is used to determine whether a firm is generating enough cash flow to cover its current liabilities. Arguably, this measure is more reliable than related liquidity measures, such as current ratio, because it accounts for changes in both the income statement and the balance sheet while eliminating the impact of accounting conventions. Firms with higher cash flow ratios to current liabilities have greater cash resources to meet their financial obligations. Conversely, low liquidity indicators represent risk of bankruptcy due to an inability to pay the current debts. Findings in Table-1 suggest that the minimum value of cash flow ratio is -7.12 , the maximum is 3.62 , and the average is 0.68 . The low negative value is from a firm with few liabilities and a negative cash flow. This variation in liquidity in the sample suggests that the firms examined include those facing a high risk of bankruptcy as well as trucking firms with enough liquidity to meet their financial obligations.

Table 1. Summary Statistics at the Firm-Level

Variable label	Explanation	Mean	St. Dev.	Min	Max
CRASH	Number of DOT reportable crashes per firm	74.65	121.31	5.00	660.00
FATALS	Number of crash-related fatalities per firm	2.35	4.35	0	23.00
INJURIES	Number of crash-related injuries per firm	35.90	57.82	1	332
PAY	\$/Mile for drivers with 3 years experience	0.29	0.02	0.24	0.37
UNPAID	Number of hours of unpaid time per mile driven in a typical run	0.0043	0.0034	0.0001	0.0151
PAIDVAC	Total vacation, holiday and sick pay	757.68	306.02	350.00	2000.00
RAISE	Average yearly increase in mileage pay	0.0064	0.0035	0.00	0.02
SAFEBOON	1 if firm offers a safety bonus, zero otherwise	0.57	0.50	0.00	1.00
HEALTH	Contribution of driver to health plan	160.72	67.22	0.00	368.33
LIFEINS	Amortized value of company paid life insurance	15,858.33	10,700.11	0.00	50,000.00
MILES	Miles driven by a firm in the previous year (millions)	98.30	180.40	1.50	1106.30
P. UNITS	Number of power units owned and leased by the firm	829.43	1267.99	66.00	7193.00
CF_RATIO	Cash flow ratio	0.68	1.30	-7.12	3.62
OP_RATIO	Operation ratio	0.95	0.06	0.83	1.21
LABPREV	Labor expenses per revenue ratio	0.35	0.11	0.07	0.58

4.0 SPECIFICATION OF SAFETY MODEL

A model testing structural relationships of safety investment decisions could be estimated if enough data investments available. Given the lack of such data and the constraints in quantifying the safety inputs of a trucking firm, we develop a reduced-form model of safety performance. Following Rose (1990), we assume that financial performance is exogenous to safety outcomes. Our measure of safety outcome is the total number of crashes per firm (Table 1). A second measure also examined is total injuries resulting from crashes for each firm, but all results were virtually identical to those using crashes. Thus, we focus solely on crashes here.

The Poisson family of probability distributions provides a useful stochastic specification for examining firm crash counts. Such models have been applied to safety research for airlines (Rose, 1990), automobiles (Dionne and Vanasse, 1992), and more recently to trucking (Moses and Savage, 1996; Rodríguez et al., 2003). If we assume that each mile of activity carries some probability of resulting in a crash, then the expected number of crashes for firm i , n_i , can be

modeled as a function of the crash rate per unit of exposure (million miles), λ_i , and the number of miles (in millions). We parameterize the crash rate as an exponential function of firms' characteristics to ensure that the crash rates are nonnegative. If independent variables are denoted by the vector X_i , the crash rate will be given by $\lambda_i = \exp(X_i\beta + e_i)$, where $\exp(e_i)$ is a Gamma-distributed error term that is a function of $X_i\beta$ for the i th observation¹¹, and the expected number of crashes is

$$E(n_i) = MILES_i^{\beta_0} \cdot \exp(X_i \mathbf{b} + e_i) \quad (1)$$

where β_0 is the estimated elasticity of crashes with respect to exposure. The coefficient β_0 will determine if the crash rate increases with miles ($\beta_0 > 1$), decreases ($\beta_0 < 1$) or does not change ($\beta_0 = 1$).

The gamma-distributed error term allows the variance to differ from the conditional mean of the distribution and thus is a more general expression of the Poisson regression model. If crashes are distributed as Poisson random variables with conditional mean given by (1), the model corresponds to the negative binomial model and the parameters can be estimated directly using maximum likelihood methods.

5.0 SAFETY ESTIMATION RESULTS

We begin our analysis by estimating a reduced-form model, with exposure, firm size, and our three financial indicators as independent variables. Due to the relatively low number of firms in the dataset, the three financial variables are included independently in separate models. The first set of results contains estimates using operating ratio. The second and third sets of results contain estimates from models using cash flow and labor expense per revenue ratios as

¹¹ For details, see Cameron and Trivedi (1998,70-77). Using Cameron and Trivedi's terminology, this is known as the NB2 parameterization.

the financial performance variables. Estimates of elasticities at variables' means are also provided for each of the models.¹² To determine the best-fitting model we first estimate a Poisson model, which we use as a baseline against which the more general negative binomial models can be tested. Likelihood ratio tests allow for identifying the preferred specification between the Poisson and the negative binomial model. Results for the preferred models are provided in Table 2.

Table 2. Total crashes and firm financial performance, negative binomial regression

	Operating ratio model			Cash flow ratio model			Labor costs per revenue ratio model		
	Coef.	t	Elast	Coef.	t	Elast	Coef.	t	Elast
LOGMILES	0.075		0.29	0.075	1.31	0.29	0.070	1.22	0.27
P. UNITS	0.002 ***	9.29	1.33	0.002 ***	9.01	1.31	0.002 ***	9.47	1.35
P. UNITS^2	-1.6E-07 ***	-6.82	-0.37	-1.6E-07 ***	-6.62	-0.36	-1.6E-07 ***	-6.91	-0.37
OP_RATIO	-0.963	-0.86	-0.91						
CF_RATIO				0.061	1.08	0.04			
LABPREV							-0.269	-0.46	-0.09
CONSTANT	3.430 ***	3.20		2.492 ***	11.72		2.620 ***	8.74	
ALPHA	0.178 ***			0.177 ***			0.179 ***		
Log-lik. at intercept		-318.87			-318.87			-318.87	
Log-lik. at convergence		-260.28			-260.08			-260.54	
Pseudo R^2		0.17			0.17			0.18	
LR of alpha = 0		392.51			377.39			386.46	

*** Significant at a 99% confidence level
 ** Significant at a 95% confidence level
 * Significant at a 90% confidence level

Consistent with expectations of overdispersion because the variance of crashes exceeded the mean, results suggest that the negative binomial model was the preferred model. The overdispersion parameters in the negative binomial specification always are significantly different from zero at high levels of confidence. The overall fit of the models seem adequate, with all of them explaining between 16.5 and 18.3% of the log-likelihood of a constant-only

¹² For a given independent variable X_j , the elasticity is evaluated numerically as $\frac{\partial \log E(n_i)}{\partial \log(X_{ji})}$ at the means of the independent variables (see Table 1).

model. Adjusting for the degrees of freedom, the models explain between 16.4 and 16.6% of the log likelihood of a constant-only model.

5.1 Estimated influence of financial performance on crash frequency

None of the financial coefficients of interest are statistically significant. Across equations, other coefficients have consistent signs and levels of significance. The coefficient for power units and its square term suggest that the larger the firm, the higher the crash frequency but at a decreasing rate. By contrast, the coefficient for the log of miles traveled is not statistically significant, suggesting that the crash rate decreases with miles and independent of the size of the firm, as measured by the number of power units.. A model constraining the coefficient for the log of miles to one (not shown), which is equivalent to modeling crash rate (crashes per million miles) instead of the crash frequency, produced similar results.

Even though we found no systematic differences in crash rates based on financial performance, it is possible that these effects are significant depending on the size of firm. Smaller firms, for example, have a limited ability to institutionalize safety practices and thus may rely more on the human capital of their drivers for safe driving. Likewise, in the highly competitive truckload sector, smaller trucking firms may be more vulnerable to sudden shifts in market demand than larger firms. Similarly, larger firms may provide additional institutional means for safe driving such as stronger maintenance programs and institutionalized safety departments (including trained safety directors), as well as the resources allowing the firms to participate in safety contests and other performance-enhancing learning activities. To examine this hypothesis, we grouped firms into three categories – small, medium, and large – according to the number of power units owned or leased by the carrier. Firms with fewer than 100 power units were classified as small, whereas firms with more than 1000 power units were classified as

large. An interaction term between the financial performance measure and firm size is used to test our hypothesis which results in three variables for operating ratio (OR_SMALL, OR_MEDIUM, OR_LARGE), cash flow ratio (CF_SMALL, CF_MEDIUM, CF_LARGE) and labor expense per revenue ratio (LR_SMALL, LR_MEDIUM, LR_LARGE). Table 3 shows results following a similar format as before.

Table 3. Total crashes and financial performance by firm size, negative binomial regression

	Operating ratio model			Cash flow ratio model			Labor costs per revenue ratio model		
	Coef.	T	Elast	Coef.	t	Elast	Coef.	t	Elast
LOGMILES	0.056	1.00	0.22	0.070	1.28	0.27	0.058	1.03	0.22
P. UNITS	0.001 ***	6.32	1.24	0.002 ***	8.21	1.33	0.002 ***	6.61	1.32
P. UNITS^2	-1.5E-07 ***	-4.99	-0.34	-1.6E-07 ***	-6.28	-0.36	-1.6E-07 ***	-5.29	-0.36
OR_SMALL	-1.245	-1.14	-0.08						
OR_MEDIUM	-0.582	-0.53	-0.40						
OR_LARGE	-0.534	-0.48	-0.11						
CFR_SMALL				-0.984 **	-2.25	-0.03			
CFR_MEDIUM				0.093	1.58	0.04			
CFR_LARGE				-0.010	-0.1	0.00			
LR_SMALL							-1.263 **	-2.25	-0.04
LR_MEDIUM							0.104	0.19	0.03
LR_LARGE							-0.095	-0.14	-0.01
CONSTANT	3.222 ***	3.06		2.518 ***	11.93		2.595 ***	9.33	
ALPHA	0.162 ***			0.159 ***			0.159 ***		
Log-lik. at intercept		-318.87			-318.87			-318.87	
Log-lik. at convergence		-257.00			-256.79			-257.83	
Pseudo R^2		0.19			0.20			0.19	
LR of alpha = 0		341.45			347.71			331.67	

*** Significant at a 99% confidence level
 ** Significant at a 95% confidence level
 * Significant at a 90% confidence level

The results for operating ratio suggest that there is no detectable difference in the relationship between operating ratio and safety outcomes by firm size. However, the results for the cash-flow ratio model show a statistically significant relationship between safety and small-firm liquidity. Higher liquidity in small firms is related to a lower expected number of crashes. The elasticity estimate suggests that 10 percent greater liquidity among small firms yields a 0.3 percent lower crash frequency. A similar finding is reproduced for the labor costs per revenue

ratio model, which suggests that small firms with higher labor expenses relative to their revenue have better safety outcomes. This is consistent with our hypothesis that small firms rely more on labor market selection to improve safety outcomes than larger firms.

These results suggest that efficiency wages appear to play a significant role in a labor-intensive industry like trucking, especially among smaller firms less able to manage and monitor drivers and having a greater need to align the incentives of drivers with firm incentives. While the size of the effect is small, these results suggest that it is important for public policy to encourage small firms to rely on higher driver compensation in place of the kind of driver monitoring, training, and supervision that larger firms can provide. The results also suggest that small firms are likely to suffer the most in times of tight labor markets, partly because their safety investments come from hiring better prepared drivers. Likewise, policy makers should consider whether small firms could be encouraged or required to maintain greater liquidity and driver compensation as a safety measure. This consideration could be undertaken either within the formal regulatory framework (regulation) or the informal regulatory framework (insurance pricing and monitoring).

5.2 Influence of compensation factors on crash frequency

While the primary interest of our study is on the relationship between firm financial performance and driver safety outcomes, we take advantage of the richness of the data to examine whether driver compensation policy is related to driver safety outcomes. To reiterate, empirical evidence (e.g., Hirsch, 1993; Belzer et al., 2002; Rodriguez et al., 2003; Monaco and Williams, 2000) provides support for the idea that compensation helps to explain firm safety outcomes. In the context of our study, driver compensation is an explicit measure of firms' safety investments. Of course, firms can make investments in other safety areas not observed

here, like in improved vehicle maintenance, or in technology. Nonetheless, we consider it important to include explicit measures of safety investments, while using firm financial performance and driver compensation to account for unobserved investments. Furthermore, this differs from previous analyses in that our measurement of compensation goes well beyond per mile rates to include pay raises (RAISE), uncompensated non-driving time (UNPAID), safety incentives, (SAFECON), and benefits (PAIDVAC, HEALTH, LIFEINS).

All the compensation variables were introduced simultaneously as a block to a regression equation that included each of the financial performance measures by firm size. Results for the model including compensation variables are provided in Table 4. A test of the hypothesis that the compensation coefficients are simultaneously equal to zero can be rejected at a 89% level of confidence, at a 95% level of confidence, and at a 93% level of confidence for the operating ratio, cash flow, and labor cost per revenue ratio models, respectively. From a statistical standpoint, this suggests that inclusion of the compensation variables, as a block, appears warranted. Most models explain around 21% of the log-likelihood of a constant-only equation. As in the previous equations, alpha is greater than zero, indicating that the negative binomial specification is preferred to a Poisson specification. The coefficients and elasticities for the firm financial performance variables remain similar to those obtained in Table 3, with one exception. The liquidity measure for the medium-sized firms (cash flow ratio model) becomes marginally significant at 90% level of confidence.

Throughout the three models, two compensation variables emerge as consistently related to crash outcomes: UNPAID and HEALTH. The former measures the number of hours of unpaid time per mile driven in a typical run, and the coefficient is positive, as expected. The greater the number of unpaid work hours per mile driven, the higher the number of crashes in the

firm. HEALTH measures the driver's monthly contribution to a health plan. A higher number represents a reduction in compensation, offsetting higher wage rates. Unexpectedly, the coefficient for this variable is negative, indicating that the higher the average driver contribution, the lower the crash frequency. Although explanations for this result are possible, the quality of the health plan available to drivers should be observed before speculating about the meaning of this result. For example, it is possible that employees pay more for better quality health plans (access to any private health facility versus an HMO). Thus, risk averse employees are likely to subscribe to the more expensive plan and such risk aversion may transfer to work habits, as they may be more likely to be safer employees

Table 4. Total crashes, financial performance by firm size, and compensation variables negative binomial regression

	Operating ratio model			Cash flow ratio model			Labor costs per revenue ratio model			
	Coef.	T	Elast	Coef.	t	Elast	Coef.	t	Elast	
PAY	-2.129		-0.81	-0.62	-0.996	-0.39	-0.29	-1.185	-0.42	-0.34
UNPAID	43.662 **	2.49	0.19		44.942 **	2.59	0.19	53.998 ***	3.09	0.23
PAIDVAC	3.5E-04	-1.48	-0.27		3.4E-04	-1.48	-0.26	3.3E-04	-1.35	-0.25
RAISE	-12.296	-0.65	-0.08		-6.776	-0.36	-0.04	7.197	0.37	0.05
SAFEON	-0.097	-0.85	-0.05		-0.117	-1.01	-0.07	-0.094	-0.84	-0.05
HEALTH	-0.003 ***	-2.76	-0.45		-0.003 ***	-3.12	-0.51	-0.003 ***	-2.95	-0.49
LIFEINS	-4.0E-06	-0.8	-0.06		-4.0E-06	-0.81	-0.06	-4.0E-06	-0.88	-0.07
LOGMILES	0.038	0.69	0.15		0.035	0.67	0.14	0.023	0.43	0.09
P. UNITS	0.001 ***	6.21	1.17		0.002 ***	8.80	1.29	0.001 ***	6.09	1.23
P. UNITS^2	-1.4E-07 ***	-4.75	-0.31		-2E-07 ***	-6.56	-0.35	-1E-07 ***	-4.69	-0.33
OR_SMALL	-1.670	-1.58	-0.11							
OR_MEDIUM	-1.054	-0.98	-0.72							
OR_LARGE	-0.849	-0.79	-0.17							
CFR_SMALL					-1.165 **	-2.59	-0.03			
CFR_MEDIUM					0.091 *	1.65	0.04			
CFR_LARGE					0.038	0.37	0.01			
LR_SMALL								-1.798 ***	-3.05	-0.06
LR_MEDIUM								-0.205	-0.37	-0.05
LR_LARGE								0.048	0.06	0.00
CONSTANT	5.080 ***	3.62			3.672 ***	4.82		3.775 ***	4.21	
ALPHA	0.127 ***				0.121 ***			0.120 ***		
Log-lik. at intercept		-318.87				-318.87			-318.87	
Log-lik. at convergence		-252.10				-250.24			-250.06	
Pseudo R^2		0.21				0.22			0.22	
LR of alpha = 0		187.30				206.19			185.33	

*** Significant at a 99% confidence level

** Significant at a 95% confidence level

* Significant at a 90% confidence level

Finally, no other compensation variables are statistically significant at standard levels of confidence. Although this may be more a result of the small sample size than of the relationship between individual variables and crashes, it is surprising to find that PAY and PAIDVAC and SAFECON are not statistically significant. In addition to sample size, other factors may contribute to improving the explanatory power of the model, such as additional driver-level factors (e.g. driving ability and ability to tolerate fatigue), vehicle factors (vehicle condition), other occupational factors (time spent waiting for loads, or loading and unloading, regularity of schedule, and hours worked/awake), and environmental factors (weather and quality of roads).

6.0. CONCLUSIONS

Recent research has shown that financial performance measures, firm characteristics, operation characteristics, and human capital factors have an important influence on crash involvement. Using a distinct methodological approach and a unique dataset, this research provides evidence showing that such factors tend to be important predictors of frequency of crash involvement. In particular, this study finds that low liquidity and low labor expenses per revenue of trucking firms with fewer than 100 power units are correlated with high crash frequencies. This supports our hypothesis that small trucking firms can invest in safety by devoting more resources to driver compensation, thereby improving safety outcomes. In contrast, a firm's operating ratio was not significantly related to crash frequency.

In a second model specification we also test the hypothesis, from conventional economic theory, that firms paying higher compensation to workers should have better quality workers and have fewer crashes. Compensation variables examined include direct compensation, safety, vacation and health benefits. As expected, we find some evidence showing that firms offering greater compensation experienced a lower crash frequency, controlling for financial measures.

However, the coefficients for the direct compensation variable, pay rate, were not statistically significant. One explanation for this could be that pay is an endogenous variable that has been treated as exogenous in a model designed to capture financial effects.

A limitation of this study is the small number of firms available in the dataset. Although there is a strong potential for continued research relying on the merger of two or more trucking industry and federal/state data sources, the process of merging data may propagate the shortcomings of various sources. The Signpost dataset includes most of the larger carriers and excludes thousands of smaller carriers. This bias toward the bigger carriers shrinks the sample size and excludes thousands of small carriers, which our models suggest may have the biggest safety problems in combination with low liquidity and driver compensation. On the other hand, Financial and Operating Statistics data cover only large firms in interstate commerce, and despite the obligation to file this form, only a relatively small fraction of firms do so. It also is plagued by missing values in a number of data elements. Despite this, the empirical findings suggest it is important to account for carrier economic condition and for the level of investment in human capital in the study of truck safety. The effort demonstrated in this study provides a basis for future research on firm financial factors affecting truck driver safety.

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