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CHARACTERISTICS OF MOTOR CARRIERS OF HAZARDOUS MATERIALS

Leon N. Moses
Ian Savage
Department of Economics & the Transportation Center
Northwestern University
2003 Sheridan Road
Evanston, Illinois 60208, USA

ABSTRACT

This paper investigates whether trucking firms that haul hazardous materials differ from firms who do not haul these goods. It employs a database of 75,000 federal government safety audits of United States motor carriers. We find that hazardous materials firms are five times larger, in terms of annual fleet miles, than non-hazardous materials haulers, and are more likely to be general commodity carriers. Based on Poisson regression analysis, firms that carry hazardous materials exclusively have an accident rate 11% higher than comparable firms that do not carry these commodities, and a rate of fatalities and serious injuries that is 22% higher. Firms that carry hazardous materials in combination with general freight, have an accident rate that is 18% higher and a fatality and injury rate that is 24% higher.

Among hazardous materials carriers, accident rates decline with firm size. Private carriers are safer than for-hire carriers. Haulers of gases in packages and liquids in tanks have the highest accident rates. Carriers of hazardous wastes have the lowest accident rates. Firms classified as "unsatisfactory" in safety audits by the federal government have an accident rate 50% worse than other firms, though these accidents do not result in a higher incidence of fatalities and injuries.

1. INTRODUCTION

This paper investigates whether the trucking firms that carry hazardous materials differ from firms that do not carry such goods in terms of characteristics, such as size, and their accident experience. The paper contains two groups of analyses. The first makes comparisons between carriers of hazardous and non-hazardous materials to see if their physical characteristics, accident experience, and compliance with safety regulations differ. The second deals solely with the hazardous materials carriers. We report on an investigation that is designed to establish whether certain types

of cargoes are more risky, and whether firm characteristics such as size, age and compliance with safety regulations influence accident rates.

The paper extends work that was reported at a Northwestern University conference in 1991 (Moses and Savage, 1991). As a result of the interest generated by that paper, the authors approached the Federal Highway Administration (FHWA) to obtain a larger database. The FHWA made available their entire record of motor carrier safety audits. Consequently in our present study we are able to expand the number of observations from 13,000 firms, of which 2,000 carried hazardous materials, to 75,500 firms, of which 13,500 carry hazardous materials. Some of the results obtained with the larger data set differ in non-trivial ways from those of the first paper.

2. DATA SOURCES

The data for the investigation are derived from the initial "Safety Review" audits of U.S. interstate motor carriers that are mandated by the 1984 Motor Carrier Safety Act. In the course of these audits, data are collected on firms' physical characteristics, goods carried, accident record, and compliance with federal motor carrier safety regulations. The data are kept in the FHWA's Motor Carrier Management Information System (MCMIS). We obtained the entire database for 92,529 firms that were audited between October 1986 and November 1991. We removed from the dataset Canadian and Mexican firms, bus companies, and firms that did not operate any trucks. We then cleaned the data by removing obvious data entry errors. As a result we have a useable dataset of 75,577 firms of which 13,498 (18%) indicated they carry hazardous materials.

3. ANALYTICAL METHOD

In our analyses we adopt a type of regression technique based on the Poisson distribution in preference to the more common, ordinary least squares (OLS) approach. Professional opinion suggests that the Poisson distribution offers several distinct advantages when dealing with count data (Cameron and Trivedi, 1986; Hausman, Hall and Griliches, 1984). It has been applied to accident data for the airlines (Rose, 1990) and the shipping industry (McCullagh and Nelder, 1983).

In the Poisson formulation the number of accidents is the dependent variable, the explanatory variables are multiplicative and one takes the exponent of a coefficient in order to interpret it. Exposure to accidents, interpreted as truck miles in our study, is one of the explanatory variables. This contrasts with OLS style regressions which typically have accident rates (accidents per mile) as the dependent variable. The Poisson regression is by definition non-linear and fits an exponential curve to data.

As measures of goodness of fit, the percentage of variation in the dependent variable explained by the regression and the log-likelihood statistic are typically presented. The latter statistic is usually compared to the log-likelihood of a regression with only a constant. However, because accidents are heavily related to exposure we felt that the correct base would be a regression with a constant and the log of fleet miles.

A major advantage of the Poisson regression process is that it can deal effectively with datasets where a large proportion of the observations on the dependent variable, i.e. accidents, take the value zero. Previous work, using OLS analysis on truck accident rates, have experienced difficulty in this regard (Corsi et al., 1984, 1988, 1989). The underlying Poisson nature of accident occurrence has a specific assumption that the mean and the variance of the accident distribution are identical. This equivalence leads to heteroscedasticity, a serious econometric problem in any OLS regression albeit one that most statistical packages can correct for. Corsi et al. recognize this problem and try to cope with it by taking the natural logarithm of accidents, the dependent variable. However, this creates a second problem. Many firms have zero accidents in a given year and the logarithm of zero is undefined. Corsi et al. add an arbitrary constant to the accident rate of each firm in an effort to avoid this second problem.

4. VARIABLES EMPLOYED

4.1 The Accident Experience of the Firm in the previous 365 Days

Accident data are notoriously unreliable in the trucking industry. The widely used national truck accident database of the FHWA's Office of Motor Carriers is flawed because accidents are self-reported. It is generally believed that there are serious inconsistencies and under-reporting of damage-only accidents. Our data come from questions asked directly of managers by inspectors, and therefore should be more reliable. In previous analyses (Moses and Savage, 1991, 1992) the accident measures used were the total accident experience of firms, and the total number of fatalities and injuries. The FHWA ceased collecting these data in audits conducted after November 1, 1990 and turned instead to a measure called "reportable accidents". Reportable accidents are defined as accidents involving a fatality, an injury, or more than approximately US$5,000 in property damage.[1] We also use the total fatalities and injuries measure in our analyses, but must then limit ourselves to the audits conducted prior to November 1, 1990. We did this because we felt that carriers of particularly hazardous materials might be more scrupulous about keeping records of property-damage-only accidents, but that record keeping of fatality and injury data would be more consistent across carriers.

4.2 The Log of Total Fleet Miles of the Firm in the Past Year

We use these data to capture both the amount of exposure to accidents and any firm size effects on accident rates. Testing of the coefficient against 1 determines whether accidents increase more or less than proportionately with miles. Inclusion of this variable allows us to colloquially refer to "accident rates" when interpreting the coefficients on other explanatory variables.

[1]If a correlation is calculated between reportable accidents and total accidents, using those inspections prior to November 1, 1990, we find a correlation of 0.82. Analyses that we have conducted have revealed that by dealing with reportable accidents exclusively we exclude a large number of minor, damage-only accidents that result from urban pick-up and delivery operations.

4.3 The Percent of Drivers Employed on Trips over 100 Miles

We hypothesized that firms whose primary work involves short distances, typically in urban areas, would have a different accident experience from firms whose operations primarily involve long distance service on the Interstate Highway System, or rural highways. Urban firms may be involved in a higher number of accidents, but many of these will be minor property-damage-only accidents which are not included in the federal definition of a reportable accident. This variable cannot be expressed in logarithms because several firms report zero long distance drivers.

4.4 Private Carrier Status

We use a dummy (0-1) variable to indicate if the firm is a private carrier rather than a for-hire carrier.

4.5 The Type of Goods Hauled

As part of the audit, firms complete a "census" form describing their operations. The census form lists 25 categories of non-hazardous goods and 21 sub-categories of hazardous goods from which the firm can specify what cargoes they carry. They can classify themselves in as many categories as they wish.

The data only permit the determination of whether hazardous materials are carried or not. We cannot tell what proportion of a firms business hazardous materials represent, although we can tell whether a firm is a general freight carrier. This allows us to differentiate between carriers, such as bulk tank-truck firms, which are likely to be exclusively hazardous materials haulers and other firms, especially the large less-than-truckload (LTL) operations, that may have a very small proportion of their ton-miles being hazardous materials.

As has already been stated, firms indicate which of 21 categories of hazardous materials they carry. In addition, they indicate whether the commodity is carried in tanks or packages or both. Packages seem to be the most common way of moving most hazardous materials. We decided to consolidate the potential 42 categories, 21 hazardous materials and 2 kinds of packaging, into nine categories. The primary motivation was to avoid collinearity. A correlation table was used in deciding on the consolidations. After the consolidations were carried out, we found that on average firms carried 1.6 of the 9 categories. The nine groups appear below. The amalgamations are shown in parentheses:

- Explosives (combination of categories explosives A, explosives B, explosives C, and blasting agents);
- Liquids in tanks (flammable liquids, corrosives, oxidizers and combustible liquids);
- Liquids in packages (flammable liquids, corrosives, oxidizers and combustible liquids);
- Gases in tanks (flammable gas, non-flammable gas);
- Gases in packages (flammable gas, non-flammable gas);
- Poisons (poison A, poison B);
- Radioactive materials;
- Hazardous wastes; and

- Other hazardous commodities (flammable solid, organic peroxide, irritating material, "other regulated materials", etiologic agent, "hazardous substances", and cryogenics).

4.6 The Log of the Years of Experience of the Firm

A difficulty in our investigation is that the data available to us are dates of incorporation rather than initial year of operation. This restricted the analysis of this variable to the 91% of the hazardous materials firms who are incorporated. It is, of course, true that many firms operated as a sole proprietorship or partnership prior to incorporation. Other authors have tried to base age on the date that carriers were issued their operating rights by the Interstate Commerce Commission (ICC). However, this procedure also has a weakness. Our data reveal that there are corporate firms that operated for years prior to ICC certification.

4.7 Performance in the Federal Safety Audit

Federal and State inspectors visit the operating bases of firms and make assessments of carriers' compliance with federal safety regulations and safety management policies such as those governing maintenance, driver hiring and training. The inspectors examine records and interview management officials, but do not actually inspect any equipment or test drivers. The inspectors have a standard list of 75 questions. They mark a pass or fail on each question, but can also append comments and supporting documentation. The carrier is then rated as satisfactory, conditional or unsatisfactory based on the answers to the questions, and a weighting scheme that is not known to the public. Firms that appear to have questionable safety practices, yet have not actually violated federal regulations are typically rated conditional pending further investigation.

The question of the effectiveness of these audits has been addressed by the authors elsewhere (Moses and Savage, 1992). For the purposes of this paper, we represent the audits by employing a dummy variable to indicate firms that are rated unsatisfactory. Summary statistics indicate that satisfactory and conditional firms have broadly similar accident rates, while those for unsatisfactory firms are much worse.

5. COMPARISON OF CARRIERS OF HAZARDOUS AND NON-HAZARDOUS MATERIALS

5.1 Overall Means

Mean values of various leading characteristics were calculated for the 13,498 carriers of hazardous materials and 62,079 carriers of non-hazardous materials. Standard t-tests were conducted to see whether the two groups are significantly different. The results are shown in Tables 1. The leading conclusions are:

- Hazardous materials carriers are five times larger than carriers of non-hazardous materials in terms of fleet mileage.

- Hazardous materials firms are 2½ times more likely to be general commodity carriers. This, combined with the first conclusion, suggests that a large proportion of hazardous materials are carried by the very large LTL firms.

- About two thirds of the firms that haul hazardous materials are private carriers. The proportion is about the same for the non-hazardous commodity groups.

- Hazardous materials firms are 20% more likely to be incorporated.

- Based on group means, hazardous materials carriers have an accident rate 7% higher than that of carriers of non-hazardous materials, and a rate of fatalities and injuries that is 19% higher.

Table 1: **Comparison of carriers of hazardous and non-hazardous commodities**

	Hazardous	Non-Hazardous	t-statistic
Number of Firms	13,498 (18%)	62,079 (82%)	
Average Annual Fleet Miles	1,823,200	342,000	24.17
Percent Private Carriers	64%	63%	2.19
Percent General Freight Firms	22%	9%	34.70
Percentage of Firms Incorporated	91%	74%	56.15
Average Years since Incorporation	21.6	19.3	13.27
Average Percent of Drivers Employed on Trips over 100 Miles	60%	67%	15.15
Percent Rated Satisfactory	66%	45%	46.26
Percent Rated Conditional	28%	46%	41.36
Percent Rated Unsatisfactory	5%	9%	18.19
Reportable Accidents per Million Miles	0.67	0.63	2.61
Fatalities and Injuries per Million Miles[1]	0.49	0.41	4.47

[1] For audits conducted prior to November 1, 1990.

5.2 Multiple Regression Approach

One cannot draw strong conclusions on relative accident rates from simple comparisons of means. For example, hazardous materials firms are very large, and in earlier work we found that large firms have lower accident rates than small firms (Moses and Savage, 1992). A Poisson multiple regression approach is therefore used.

The results for the regressions on reportable accidents, and total fatalities and injuries are shown in table 2. We do not concern ourselves with the interpretation of variables other than the dummy variables for hazardous materials carriers at this point. The other variables are discussed at length in section 6 below, which deals with the hazardous materials carriers.

Table 2: **Multiple regression incorporating hazardous materials variables**

Dependent variable	Reportable Accidents	Fatalities & Injuries
Audit Dates	All Audits	Before 11/1/90
Observations	75,577	62,532
Proportion of Variation Explained	0.80	0.66
Log-Likelihood	- 37,469	- 27,374
Log-likelihood(log of miles and constant)	- 38,027	- 27,751
Explanatory variables (with t statistics in parentheses)		
Constant	-13.719 (283.30)	-14.330 (229.70)
Log of Total Fleet Miles^{+}	0.963 (12.10)	0.971 (7.48)
Percent of Drivers Employed on Trips over 100 Miles	0.017 (0.97)	0.150 (6.51)
Dummy Variable - Private Carrier	- 0.261 (17.02)	- 0.317 (15.86)
Dummy Variable - General Freight and Hazardous Materials	0.167 (10.21)	0.217 (10.61)
Dummy Variable - Hazardous Materials Only	0.101 (5.94)	0.195 (9.07)
Dummy Variable - Rated Unsatisfactory	0.686 (27.44)	0.546 (15.32)

+ The coefficient on miles is compared against 1 so as determine the effect of fleet miles on accident rate per mile.

Carriage of hazardous materials is represented by two dummy variables. The first indicates firms who carry hazardous materials as well as general freight. The second dummy variable identifies firms that only transport hazardous materials, i.e. they do not also carry general freight. There are approximately 3,000 firms in the first category, and 10,500 in the second. Thus the regression allows a comparison of the accident rates of three kinds of firms: 1) those that do not carry any hazardous materials; 2) those firms that carry hazardous materials as well as general freight; 3) those that carry hazardous materials exclusively. The coefficients on the hazardous materials dummy variables are interpreted below:

	Effect of Dummy Variable on Accident Rates	
	Reportable Accidents	Fatalities & Injuries
Hazardous Materials & General Freight	+18.2% (t=10.21)	+24.2% (t=10.61)
Hazardous Materials Only	+10.6% (t= 5.94)	+21.5% (t= 9.07)

We find that firms that carry hazardous materials exclusively have lower accident rates than those that carry both general freight and hazardous materials. However, the accident rates of firms that carry hazardous materials, whether alone or in combination with general freight, are higher than the accident rates of those that do not carry hazardous materials.

It might be argued that hazardous materials firms may be more scrupulous in recording accidents than others. However, the fatality and injury regression supports the finding of a higher accident rate. It is difficult to accept the proposition of reporting bias for this category of accidents.

Moreover, further support for this position comes from the government safety audits, which show that firms who haul hazardous materials are *more* likely to be deficient in reporting accidents than non-hazardous materials firms.[2]

6. ANALYSIS OF THE HAZARDOUS MATERIAL CARRIERS

We now turn our attention to the 13,498 firms that indicated they carry hazardous materials. Initially we classify these firms by the specific hazardous cargoes they carry, and then compare the characteristics of these various sub-groups. We then use a multiple regression model to explain the accident rates of the sub-groups. In this latter analysis we comment on the effect of firm size, age and other characteristics, as well as the impact of performance in the safety audit on accident experience.

6.1 Characteristics of Firms that Haul Different Hazardous Cargoes

In table 3 a comparison is made of the leading characteristics of the firms that haul the various hazardous materials.

Table 3: **Comparison of firms hauling various hazardous cargoes (in descending order of average fleet mileage)**

Commodity	% Long Distance	% General Freight	% Private	Incorporation %	Fleet Miles
Radioactive	64*	54*	30*	96*	22,100,000*
Explosives	62*	44*	51*	95*	10,100,000*
Poisons	63*	45*	43*	96*	8,600,000*
Hazardous Wastes	75*	13*	52*	93	5,100,000*
Other Hazardous Commodities	64	35*	54*	95*	4,100,000*
Gases in Packages	54*	27*	70*	93	3,900,000*
Liquids in packages	63*	34*	57*	93	2,700,000*
Gases in Tanks	51*	5*	75*	91*	1,400,000*
Liquids in Tanks	54*	5*	73*	90*	1,100,000*
Average	60	27	61	93	3,600,000

* indicates significantly different from average at 5% level. The average used in determining the significance may be different from that shown in table 1 as firms may carry several commodities.

[2]Question 394-3 of the federal safety audit asks if the firm complies with the reporting of accidents. 9.4% of firms who haul hazardous materials, either exclusively or as part of a general freight business, are assessed a "no" to this question, compared with 7.9% of non-hazardous materials firms. The difference is statistically significant with a t statistic of 5.57. Previous work has revealed that as the proportion of non-compliance rises accident rates increase (Moses and Savage, 1992).

The leading conclusions are:

- Tank truck companies are about a third of the size of the average hazardous materials firm in terms of fleet miles. Also, tank truck firms are more likely to be private carriers.

- Tank truck companies, and haulers of hazardous wastes are more likely to be specialized carriers, and not carry general freight.

- Haulers of hazardous wastes have a higher proportion of drivers on long trips compared with the average hazardous materials firm.[3]

- Radioactive, explosive and poisonous materials are hauled by the very largest carriers, with an average size two or more times the overall mean.

6.2 Multiple Regression Approach

Poisson regression analyses of reportable accidents, and fatalities and injuries were conducted for the 13,498 hazardous materials carriers. Explanatory variables are firm size measured by annual fleet miles; the percentage of drivers on long distance trips; a dummy variable for private carriage; dummy variables for the different categories of hazardous materials (excepting the "other" category); and a dummy variable representing an unsatisfactory audit rating. The results are shown in table 4. The coefficients in these regressions are reviewed below under two headings: firm characteristics, and the commodity carried.

Conclusions on Firm Characteristics

- Accident rates decline with firm size.

The coefficient on total fleet miles has a value significantly less than unity in both regressions, meaning that accidents increase less than proportionately with miles, i.e. the rate of accidents declines with size. In figure 1, the results are shown as an index. This index is the ratio of the predicted accident rate of a given size group to that of the smallest group of firms in our study, namely those with fleet miles of 5,000 per year. The results suggest that accident rates decline by about 23% when comparing a firm with 1½ million miles with a very small firm. Firms with annual mileage of 5 million have accident rates 27% below the very smallest firms. The rate of fatalities and injuries declines more slowly with size. Firms with annual mileage of 5 million miles have fatality and injury rates about 17% below those of the very smallest firms.

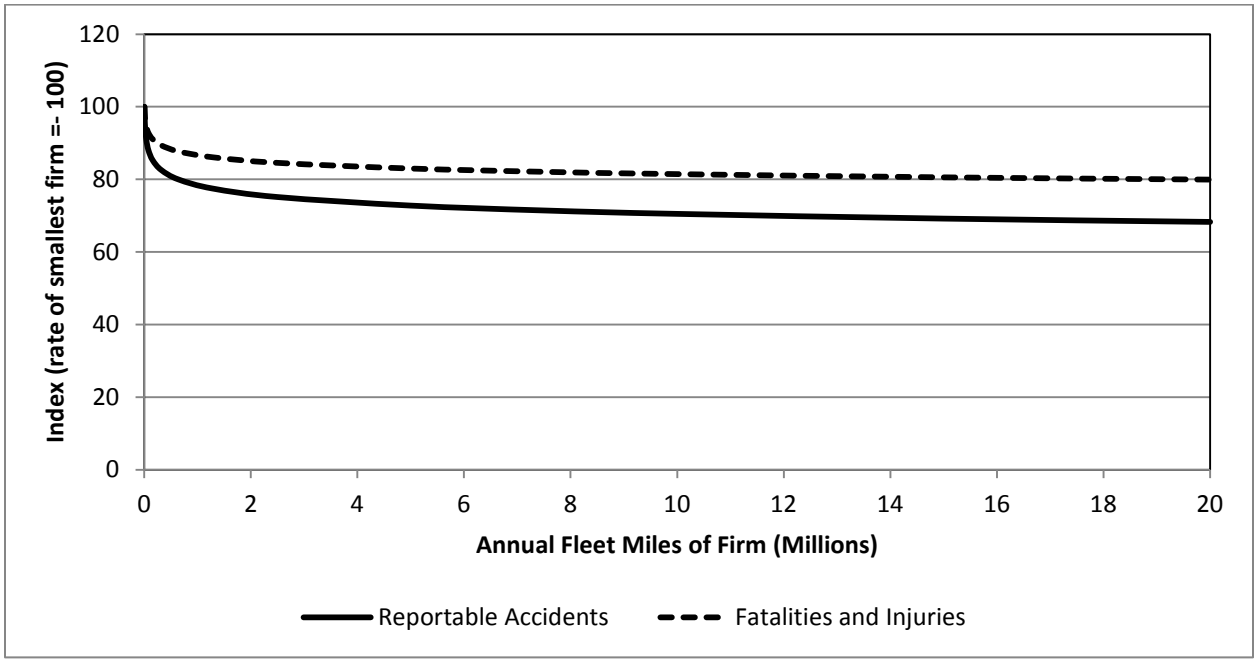
[3]Officials at the FHWA offer an explanation for this finding. The hazardous wastes industry is made up of local and line-haul operators. The large hazardous wastes corporations perform the latter function, consolidating waste collected by small local independent contractors. The federal government has poor or non-existent records on these local operators.

Table 4: **Multiple regression analysis of hazardous materials carriers**

Dependent variable	Reportable Accidents	Fatalities & Injuries
Audit Dates	All Audits	Before 11/1/90
Observations	13,498	11,732
Proportion of Variation Explained	0.86	0.74
Log-Likelihood	- 11,659	- 9,547
Log-likelihood (log of miles and constant)	- 11,904	- 9,790
Explanatory variables (with t statistics in parentheses)		
Constant	-13.680 (169.65)	-14.393 (142.97)
Log of Total Fleet Miles[+]	0.954 (9.00)	0.973 (4.20)
Percent of Drivers Employed on Trips over 100 miles	0.204 (7.37)	0.423 (11.71)
Dummy Variable - Private Carrier	- 0.294 (12.07)	- 0.409 (13.16)
Dummy Variable - Explosives	0.015 (0.65)	0.011 (0.37)
Dummy Variable - Liquids in Tanks	0.071 (2.94)	0.086 (2.92)
Dummy Variable - Liquids in Packages	- 0.019 (0.77)	- 0.015 (0.48)
Dummy Variable - Gases in Tanks	- 0.169 (4.23)	- 0.038 (0.81)
Dummy Variable - Gases in Packages	0.115 (5.54)	0.099 (3.95)
Dummy Variable - Poisons	0.025 (1.07)	- 0.002 (0.08)
Dummy Variable - Radioactive	0.205 (7.60)	0.033 (1.00)
Dummy Variable - Hazardous Wastes	- 0.133 (5.34)	- 0.178 (5.70)
Dummy Variable - Rated Unsatisfactory	0.425 (8.29)	0.002 (0.03)

[+] The coefficient on miles is compared against 1 so as determine the effect of fleet miles on accident rate per mile.

Figure 1: **Index of Accident rate by Firm Size**



- Long distance operations are associated with higher accident rates.

Long distance operators, defined as firms whose drivers are all involved in trips that exceed 100 miles, have a total accident rate that is 22% higher than that of firms that are exclusively involved in short distance operations, and a rate of fatalities and injuries that is 53% higher. This result is not surprising. The measures of accidents used in this analysis include only the most serious incidents. While one would expect that congested urban areas would have the highest number of accidents of all kinds, most of the accidents that do occur are minor in nature. The accidents on long distance trips tend to be more serious and result in a higher rate of accidents that involve fatalities and serious injuries, as well as more property damage.

- Private carriers appear to have accident rates that are about 30% lower than those of comparable for-hire carriers. This is true for both reportable accidents, and fatalities and injuries.

- Reportable accident rates do not vary with firm age.

We also decided to investigate the effect of firm age on accident performance, using as our variable the number of years since incorporation. Unfortunately, 9% of the firms are not incorporated, and hence regressions including this variable are restricted to corporate firms. To save space, the full regressions are not shown. In the reportable accidents equation, the coefficient on the log of years of experience variable was insignificant taking the value -0.001 with a t-statistic of 0.13. In the equation for fatalities and injuries, the coefficient was positive, 0.06, with a t-statistic of 4.45. The coefficient implies that a firm that has been incorporated for thirty years has an accident rate that is 22% greater than a newly incorporated firm. What should be borne in mind in interpreting this counter-intuitive result is that the inclusion of the experience variable reduces the size of the log of miles coefficient from 0.973 to 0.961. Apparently, the negative effect of size on the rate of fatalities and serious injuries is smaller in the equation that does not include the experience variable. The positive age effect of a firm that has been incorporated for many years is balanced by a more pronounced negative size effect.

- Firms who are rated unsatisfactory in government safety audits have reportable accident rates 53% higher than firms rated conditional or satisfactory, though these additional accidents do not result in a higher incidence of fatalities and injuries.

This result may appear to be somewhat surprising because the regression results for the full sample of 75,577 firms, shown in table 2, suggest that unsatisfactory firms have both a 90% higher rate of reportable accidents and a 75% higher rate of fatalities and injuries compared with firms rated conditional or unsatisfactory. The implication of these results is that, *ceteris paribus*, the unsatisfactory firms who have an inordinately high rate of fatalities and injuries are primarily those who do not carry hazardous materials.

Conclusions on Hazardous Commodity Hauled

We report the percentage effect on accident, and fatality and injury, rates that are derived from our multiple regression in table 5. Our major conclusions are:

- Carriers of gases in packages and liquids in tanks have the highest rates of accidents and fatalities and injuries. They are 10% above that of carriers who do not haul commodities in these groups.

- Carriers of gases in tanks have a rate of fatalities and injuries that is no different from carriers that do not haul this commodity. However, the rate of reportable accidents is 15% less. The difference in the two percentages suggests that the carriers of this product type tend to have accidents that involve high rates of personal injury and death.

- Carriers of radioactive materials appear to have a high reportable accident rate, one that is 23% above that of firms that do not carry commodities in this group. However, it is likely that this finding is due to scrupulous record keeping by this type of carrier, because the rate of fatalities and injuries is not significantly different from that of other carriers.

- Haulers of hazardous wastes have considerably lower accident, and fatality and injury, rates than do other hazardous materials carriers. The difference is about 15%. As discussed earlier, the database only covers line-haul operations of wastes. The data do not permit implications to be drawn about the safety of operators who provide local collection of hazardous wastes.

Table 5: **Effect on accident rates of hauling specific hazardous commodities (in descending order of effect on fatalities and injuries)**

	Predicted Percent Effect on	
	Reportable Accidents	Fatalities and Injuries[1]
Gases in Packages	+12.2%*	+10.4%*
Liquids in Tanks	+ 7.4%*	+ 9.0%*
Radioactive	+22.8%*	+ 3.4%
Explosives	+ 1.5%	+ 1.1%
Poisons	+ 2.5%	- 0.2%
Liquids in Packages	- 1.9%	- 1.5%
Gases in Tanks	-15.5%*	- 3.7%
Hazardous Wastes	-12.5%*	- 16.3%*

* Indicates statistically significant, from firms who do not carry this commodity, at the 5% level.
[1] For audits conducted prior to November 1, 1990.

7. CONCLUDING REMARKS

7.1 Comparisons with Non-hazardous Materials Carriers

- Hazardous materials carriers are five times larger than carriers of non-hazardous materials in terms of annual fleet miles. They are much more likely to be incorporated, and also to be general commodity carriers.

- Firms that carry hazardous materials exclusively have an accident rate 11% higher than comparable firms that do not carry these commodities, and a rate of fatalities and serious injuries that is 22% higher. Firms that carry hazardous materials in combination with general freight, have an accident rate that is 18% higher and a fatality and injury rate that is 24% higher.

7.2 Comparisons between Carriers of Different Hazardous Materials

- Radioactive, explosive and poisonous materials are hauled by the very largest carriers of hazardous materials.

- Tank truck companies are about a third the size of the average hazardous commodity carrier in terms of fleet miles.

- Gases in packages and liquids in tanks are the most dangerous commodity groups in terms of accident rates.

- Accidents involving gases in tanks result in a higher than average incidence of personal injury and death.

- Line-haul carriage of hazardous wastes has a significantly lower accident rate than carriers of other hazardous materials.

- Among hazardous materials carriers, accident rates decline with firm size. Private carriers are 30% safer than for-hire carriers.

- Carriers rated unsatisfactory in federal safety audits have an average reportable accident rate that is 50% higher than that of firms rated conditional or satisfactory, though these accidents do not result in a higher incidence of fatalities and injuries.

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REFERENCES

CAMERON, A.C., & TRIVEDI, P. (1986). Econometric models of count data: Comparisons and applications of some estimators and tests. *Journal of Applied Econometrics*, 1, 29-54.

CORSI, T.M., & FANARA, P. (1988). Driver management policies and motor carrier safety. *Logistics and Transportation Review*, 24, 153-163.

CORSI, T.M., & FANARA, P. (1989). Effects of new entrants on motor carrier safety. In L.N. Moses, and I. Savage (Eds.), *Transportation Safety in an Age of Deregulation*. New York: Oxford University Press.

CORSI, T.M., FANARA, P., & ROBERTS, M.J. (1984). Linkages between motor carrier accidents and safety regulation. *Logistics and Transportation Review*, 20, 149-164.

HAUSMAN, J., HALL, B.H., & GRILICHES, Z. (1984). Econometric models for count data with an application to the patents-R&D relationship. *Econometrica*, 52, 909-938.

McCULLAGH P., & NELDER, J. (1983). *Generalized Linear Models*. London: Chapman and Hall.

MOSES, L.N., & SAVAGE, I. (1991). Motor carriers of hazardous materials. Who are they? How safe are they? *Proceedings of Hazmat Transport `91*. Evanston, IL: Northwestern University Transportation Center.

MOSES, L.N., & SAVAGE, I. (1992). The effectiveness of motor carrier safety audits. *Accident Analysis and Prevention*, 24, 479-496.

ROSE, N. (1990). Profitability and product quality: Economic determinants of airline safety performance. *Journal of Political Economy*, 98, 944-964.