7TH WCTR
SYDNEY AUSTRALIA
1995

TOPIC 2
MARITIME
TRANSPORT (SIG)

DETERMINANTS OF THE SHIP DAMAGE SEVERITY OF CONTAINERSHIP ACCIDENTS

WAYNE K. TALLEY
Department of Economics
Old Dominion University
Norfolk, Virginia 23529 USA

Abstract

This paper investigates determinants of the severity of containership accidents. The results suggest that the severity of ship-motion containership accidents is greater when precipitation weather exists and greater for collision than grounding accidents. Coast Guard safety patrol activity is effective at the margin in reducing ship damage severity.

INTRODUCTION

Modern ocean container transportation owes its origin to Malcom Mclean who in 1956 purchased a small shipping line (renamed Sealand) and began experimenting with the ocean movement of trailer loads of cargo from New York to Puerto Rico. Containerized cargo needed to be handled only twice—at the origin when loaded into a container and at the final destination when unloaded. The potential cost savings to the shipping line and shipper soon became apparent. Where it once took a gang of perhaps 20 longshoremen to load 20 tons of cargo per hour on a break-bulk vessel, one crane and perhaps half as many men can now load and stow 400 or more containerized tons an hour on a containership (Chadwin, Pope, and Talley 1990: 3). Furthermore, the time spent by a ship in port was greatly reduced: Where a break-bulk vessel may require a week in port to unload and reload, a containership might call for only four to six hours. Port labor costs were lowered as well as other time-related port costs such as dockage and wharfage; less time in port also meant fewer ships were needed to carry the same amount of cargo.

For the shipper, reduced ship time in port meant faster and more reliable delivery of goods. Inventories could be cut back substantially, generating significant savings in inventory costs. Less handling of containerized cargo meant less damaged cargo. Also, there was reduced loss from pilferage, since containers were sealed when loaded and unsealed at final destination. Less damaged and pilferaged cargo reduced insurance premiums, thus further reducing shipper inventory costs. During the 1970s and 1980s, perhaps 60 percent of what had been break-bulk cargo in the 1960s was containerized (Chadwin and Talley 1992: 1). This growth was spurred by the advantages of container transportation in conjunction with the growth in intermodalism, just-in-time (JIT) inventory management techniques and advances in electronic communications technologies, resulting in modern ocean container transportation being referred to as "the industrial revolution in international shipping" (Chadwin, Pope and Talley 1990: 2).

One aspect of ocean container transportation that has not been addressed in the literature is containership safety. We define this safety as the risk of a containership sustaining damage. There are two aspects of this risk: 1) the likelihood of a containership having an accident and 2) the severity of a containership accident given that an accident has occurred. The transportation safety literature heretofore has focused on the former rather than the latter. However, Moses and Savage (1990: 171) note a limitation of the former—"even if we were to define safety as the probability that a trip would end in an accident, there still would be the problem that accidents vary in severity from minor damage-only incidents to major tragedies."

The purpose of this paper is to investigate determinants of the ship damage severity of containership accidents. A micro-data set of detailed information on individual containership accidents is utilized in our investigation. Since the severity of an accident is conditioned upon the occurrence of an accident, the likelihood and the severity of an accident are expected to have common determinants. Hence, our determinants may be used by container shipping lines in their decision-making for not only reducing the severity of containership accidents but also for reducing the likelihood of a containership having an accident.

The paper is structured as follows. The next section presents a model of the ship damage severity of containership accidents. Data are discussed in the following section; the estimation results of the ship damage severity model are then detailed. Conclusions are found in the final section.

A SHIP DAMAGE SEVERITY MODEL

The ship damage severity (SDS) of a containership accident is hypothesized to be affected by the container shipping line's safety investments, operating conditions (at the time of the accident), type of ship accident, safety regulation and enforcement, and the price of ship repair. A container shipping line's safety investments consist of actions by the line to improve the safety of its containership service. Such investments include hiring more experienced vessel operators and utilizing newer and larger ships. These investments are expected to reduce the ship damage severity of containership accidents.

We measure the experience of the ship's operator by the binary variable LICENSE—equals one if the vessel at the time of the accident was manned by a licensed individual and zero if manned by an unlicensed individual. In addition to reducing the risk of an accident, a more experienced operator is also expected to lessen the severity of an accident, eg in the handling of a disabled ship. Ship age (SAGE) is measured in years. A positive relationship is expected between SAGE and SDS; ship structural failure is expected to increase with age. Ship size (SSIZE) is measured in gross tons. Ship size and seaworthiness are positively correlated, eg larger ships are less susceptible to wind and hazardous weather than smaller ships; however, it is unclear once an accident occurs whether larger ships will be susceptible to more or less damage than smaller ships. Hence, the relationship between SSIZE and SDS is indeterminate.

Operating conditions describe the environment in which a ship was operating at the time of an accident. This environment includes type of waterway utilized, phase of ship operation, and weather/visibility characteristics. We describe the type of waterway utilized as either a coastal (COAST), inland (INLAND), or ocean waterway. The expected signs of the relationships between these variables and accident ship damage severity are indeterminate. Although a containership is more likely to have an accident in the waterway where its service is concentrated, it is unclear whether this ship will incur greater accident damage in this waterway.

We describe phase of ship operation by whether the ship was adrift (ADRIFT), underway (UNDERWAY), or docked or moored. The *a priori* signs of the relationships between ADRIFT (versus docked or moored) and SDS and between UNDERWAY (versus docked or moored) and SDS are indeterminate. Although a ship that is adrift or underway (versus docked or moored) is more likely to have an accident, it is unclear once an accident has occurred whether the ship will incur greater accident damage than a docked or moored ship.

We describe the weather at the time of a ship accident in terms of precipitation (PRECIPE) versus no precipitation (eg rain and snow), wind speed (WIND) and visibility. Although the risk of a ship accident is expected to increase with precipitation and the higher wind speed, their impact on ship damage severity is unclear—thus, their *a priori* signs are indeterminate. We differentiate visibility by time of day, ie by whether the accident occurred at night (NIGHT) versus day. Although poor visibility at night is expected to increase the risk of an accident, its impact on SDS is unclear.

The extent of ship damage severity may also vary by type of accident. Ship accidents have been classified as either collisions, fires/explosions, material/equipment failures or grounding accidents. Collisions and groundings have been termed "ship-motion" accidents, while fires, explosions and material and equipment structural failures have been termed "ship-integrity" accidents (see Meade, LaPointe and Anderson 1983). We estimate separate relationships for ship-motion and ship-integrity accidents. For the former, we describe type of accident by whether the accident was a collision (COLLISION) or a grounding accident; for the latter, we describe type of accident by whether the accident was a material/equipment failure (MAEQ-FAILURE) or a fire/explosion accident. Since it is unclear which type of accident will result in greater ship damage severity, the *a priori* relationships between ship damage severity and type of accident are indeterminate.

Although there is a worldwide trend toward parity of commercial vessel safety regulation standards, these standards still vary from country to country with those of the United States (US) among the highest in the world (Gracey 1985). We measure differences among countries' ship safety standards by a ship's country (or flag) of registry: We note whether a containership has US flag registry (US) or non-US flag registry. The relationship between ship damage severity and US is unclear, since higher safety standards do not necessarily correlate with improved safety. If higher standards are not enforced, safety may not improve. We measure the enforcement of ship safety standards (SAFETY-ENFORCE) by the number of safety patrol hours performed by the US Coast Guard.

Finally, we expect accident ship damage severity to be affected by the price of ship repair. We measure this price by a price index of ship building and repair (PRICE-REPAIR). The price of ship repair may affect ship damage severity in two possible ways. First, as this price increases, the greater will be the cost to repair ship damage. Second, rather than a positive relationship, there may also be a negative relationship: Greater repair cost may act as a stimulate for a container shipping line to promote safety in the utilization of its containerships.

DATA

We estimate the ship damage severity model utilizing detailed data of individual containership accidents that occurred in US waters for the nine year time period 1981-1989. Variables and their specific measurements appear in Table 1. Data for the variable SAFETY-ENFORCE were obtained upon request from the Coast Guard headquarters office in Washington, D.C. Price index data for the price variable PRICE-REPAIR were obtained from various issues of *Producer Prices and Price Indexes* (Bureau of Labor Statistics, US Department of Labor). Real PRICE-REPAIR was determined by dividing PRICE-REPAIR by the US Producers Price Index for all commodities (divided by 100). Data for the latter index were also obtained from various issues of *Producer Prices and Price Indexes* (Bureau of Labor Statistics, US Department of Labor). Accident ship damage severity is measured in damage costs; real SDS was determined by dividing SDS by the price index of ship building and repair (divided by 100). Data for the remaining variables were obtained from a computer tape of marine casualty information, the CASMAIN database, provided by the Coast Guard.

Table 1 Variables and their measurement

Variable	Measurement
Coastal Waterway (COAST)	1 if coastal waterway; 0 if an inland or ocean waterway
Inland Waterway (INLAND)	1 if inland waterway (eg river or lake); 0 if a coastal or ocean waterway
Night (NIGHT)	1 if night time; 0 if daytime
Precipitation Weather (PRECIPE)	1 if precipitation weather (eg rain or snow); 0 if non-precipitation weather
Wind Speed (WIND)	Knots
Collision Accident (COLLISION)	1 if a collision; 0 if a grounding
Material-Equipment Failure Accident (MAEQ-FAILURE)	1 if a material and/or equipment failure; 0 if a fire and/or explosion
US Flag (US)	1 if US flag; 0 if foreign (ie non-US) flag
Age of Ship (SAGE)	Years
Size of Ship (SSIZE)	Gross Tons
Adrift (ADRIFT)	1 if ship is adrift; 0 if underway or if docked or moored
Underway (UNDERWAY)	1 if ship is underway; 0 if adrift or if docked or moored
Licensed Manned Operator (LICENSE)	1 if manned by licensed operator; 0 if manned by unlicensed operator
Safety Enforcement (SAFETY-ENFORCE)	Annual nationwide Coast Guard safety patrol hours
Price of Ship Building and Repair (PRICE-REPAIR)	Annual price Index
Ship Damage Severity (SDS)	Ship damage cost in US dollars

Descriptive statistics (mean and standard deviation) for the variables are reported in Table 2. The mean statistics reveal that 76.4 percent of ship-motion containership accidents in our data occurred in inland waterways as compared with 35.6 percent of ship-integrity accidents. US flag containerships were involved in 57.3 percent of the ship-motion accidents as compared to 82.6 percent of the ship-integrity accidents; 90.6 percent of the ship-motion accidents involved underway containerships as compared to 84.1 percent of the ship-integrity accidents; and in 75.5

percent of the ship-motion accidents, the containership was manned by a licensed operator at the time of the accident as compared to 93.0 percent of the ship-integrity accidents.

Table 2 Descriptive statistics: mean and standard deviation[a]

Variable	Ship-Motion Accidents[b]	Ship-Integrity Accidents[c]
COAST	0.056	0.116
	(0.231)	(0.320)
INLAND	0.764	0.356
	(0.425)	(0.479)
NIGHT	0.455	0.390
	(0.499)	(0.488)
PRECIPE	0.189	0.086
	(0.392)	(0.281)
WIND	11.743	10.854
	(12.787)	(10.017)
COLLISION	0.560	
	(0.497)	
MAEQ-FAILURE		0.888
		(0.316)
US	0.573	0.826
	(0.496)	(0.380)
SAGE	13.140	12.805
	(10.287)	(10.100)
SSIZE	20,492	22,567
	(12,087)	(15,557)
ADRIFT	0.027	0.010
	(0.162)	(0.101)
UNDERWAY	0.906	0.841
	(0.293)	(0.366)
LICENSE	0.755	0.930
	(0.431)	(0.255)
SAFETY-ENFORCE	17,904	16,668
	(9,139)	(8,054)
Real PRICE-REPAIR	33.093	33.011
	(0.696)	(0.601)
Real SDS	54,765	50,714
	(194,636)	(213,156)

Notes:

[a]Standard deviations are in parentheses.

[b]Collision and grounding containership accidents.

[c]Fire, explosion and material and equipment structural failure containership accidents.

Ship damage costs are costs (eg labor and material) to be incurred or incurred to restore damaged ships to their service conditions which existed prior to their accidents. They are actual or estimated damage costs provided by owners (or their representatives) of damaged ships to Coast Guard Investigating Officers and do not include the cost of salvage, cleaning, gas freeing, or drydocking. Damage cost estimates are considered to be accurate subject to verification by Coast Guard Investigating Officers.

ESTIMATION RESULTS

Since ship accidents do not necessarily result in ship damage cost, the distribution of real SDS is censored—some observations are zero. If our ship damage severity model is estimated by ordinary least squares, a statistical technique that ignores censoring, the model's parameter estimates may be biased. By utilizing Tobit analysis which explicitly accounts for a censored dependent variable, we eliminate this source of estimation bias. Also, we reduce the chance of estimation bias from omission of relevant explanatory variables by including in our estimations an annual time trend variable (YEAR) to control for the exclusion of other causal factors (correlated with time) affecting real SDS.

Tobit estimation results of our ship damage cost model (where real SDS is the dependent variable) appear in Table 3.

Table 3 Ship damage severity: Tobit estimations[a]

Explanatory Variables	Ship-Motion Accidents	Ship-Integrity Accidents
Operating Condition Variables		
COAST	-291,220.31	22,732.04
	(223,219.7)	(64,074.94)
INLAND	-219,776.93**	27,346.92
	(92,276.05)	(52,173.27)
ADRIFT	100,456.13	282,379.50
	(260,865.30)	(220,082.00)
UNDERWAY	56,027.38	-38,347.97
	(167,340.90)	(70,957.68)
PRECIPE	270,425.62**	-30,820.09
	(111,780.50)	(71,047.82)
WIND	3,119.31	4,204.20**
	(3,686.00)	(2,022.70)
NIGHT	9,283.40	-20,869.66
	(81,663.95)	(41,749.63)
Carrier Safety Investment Variables		
LICENSE	48,987.67	4,814.82
	(159,709.70)	(137,461.10)
SAGE	-565.22	4,284.78**
	(4,231.67)	(1,950.13)
SSIZE	-0.76	-0.23
	(3.52)	(1.22)
Regulation, Enforcement, Price and Time Trend Variables		
US	-54,343.02	106,415.92
	(158,416.40)	(144,803.20)
SAFETY-ENFORCE	-10.49*	0.03
	(5.94)	(2.72)
Real PRICE-REPAIR	-89,079.65	-28,348.26
	(83,434.32)	(38,984.22)
YEAR	-5,940.14	-20,992.59**
	(23,437.12)	(10,236.31)
Type of Accident Variables		
COLLISION	270,531.08***	
	(90,301.94)	
MAEQ-FAILURE		-64,093.71
		(63,062.04)
Constant	14,698,128	42,469,154
	(48,504,733)	(21,108,914)
N	134	229
-2 x log of likelihood ratio	2,256***	3,038***

Notes:

[a] Standard errors appear in parentheses; N represents sample size.
***(**,*) Significant at the 1(5,10) percent level.

Separate estimation results are presented for ship-motion and ship-integrity containership accidents. For ship-motion accidents (ie collisions and groundings), four of the hypothesized explanatory variables are statistically significant; two of which are operating condition variables. The negative sign of the INLAND coefficient suggests that the ship damage severity is less for ship-motion accidents in inland than in ocean waterways, *ceteris paribus*. The coefficient of PRECIPE has a positive sign, suggesting that the ship damage severity is greater when there is precipitation weather at the time of the accident than when there is no precipitation. The negative sign of the SAFETY-ENFORCE coefficient suggests that the safety enforcement (or violation detection) patrol activity of the Coast Guard is effective at the margin in reducing containership damage severity. The positive sign of the COLLISION coefficient suggests that collision containership accidents are more severe than grounding accidents, *ceteris paribus*.

Tobit estimation of our ship damage cost model utilizing ship-integrity containership accidents (ie fires, explosions and material and equipment structural failures) reveals that two of the hypothesized explanatory variables are significant—the operating condition variable WIND and the carrier safety investment variable SAGE—and the time trend variable YEAR. It is interesting to note that these variables were not significant in our ship-motion accident estimation. The positive sign of the WIND coefficient suggests that the higher the wind speed at the time of a ship-integrity accident the greater the ship damage severity, *ceteris paribus*. The coefficient of SAGE has a positive sign, suggesting that the greater the age of a containership involved in a ship-integrity accident the greater the ship damage severity. The negative sign of the YEAR coefficient suggests that the ship damage severity of ship-integrity containership accidents declined over the time interval of our data set (ie 1981-1989).

CONCLUSION

This paper has investigated determinants of the ship damage severity (measured in damage costs) of containership accidents. Separate Tobit estimates of a ship damage severity model were obtained for ship-motion and ship-integrity accidents, utilizing detailed data of individual containership accidents that occurred in US waters for the time period 1981-1989. For ship-motion accidents, four hypothesized explanatory variables were significant: inland (versus an ocean) waterway with a negative coefficient, suggesting that the ship damage severity is less in an inland than in an ocean waterway; precipitation (versus non-precipitation) weather with a positive coefficient, suggesting that ship damage severity is greater when there is precipitation weather; safety regulation enforcement with a negative coefficient, suggesting that Coast Guard safety patrol activity is effective at the margin in reducing ship damage severity; and collisions (versus groundings) with a positive coefficient, suggesting that collision containership accidents are more severe than grounding accidents, *ceteris paribus*. For ship-integrity accidents, the variables, wind and ship age, were significant. The coefficient sign of the wind variable is positive, suggesting that the higher the wind speed the greater the ship damage severity; the coefficient sign of the ship age variable is also positive, suggesting that the greater the ship age the greater the ship damage severity of a containership accident, *ceteris paribus*. The time trend variable was also significant. The negative sign of its coefficient suggests that the ship damage severity of ship-integrity containership accidents declined over the time period 1981-1989.

Our results suggest that effective US government policies for reducing the ship damage severity of containership accidents include increasing Coast Guard safety patrol activity and increasing the safety regulation standards and/or enforcement of older containerships. Carrier operating policies should address reducing accident ship damage severity from adverse weather conditions related to precipitation and wind.

REFERENCES

Chadwin, M.L., Pope, J.A. and Talley, W.K. (1990) *Ocean Container Transportation: An Operational Perspective*, Taylor & Francis, New York.

Gracey, J.S. (1985) Many question value of drive for vessel safety standards, *Journal of Commerce*, May, 10C.

Moses, L.N. and Savage, I. (1990) Aviation deregulation and safety: theory and evidence, *Journal of Transport Economics and Policy* 24, 171-188.