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Vessel accident oil-spillage: Post US OPA-90

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Abstract

The vessel accident oil-spillage literature has focused on oil-cargo vessels, tankers and tank barges, implicitly assuming that these vessels incur greater accident oil-spillage than other (i.e., non-oil-cargo) vessels which just carry oil in their fuel tanks. This study investigates the validity of this assumption for the post US OPA-90 (Oil Pollution Act of 1990) period by investigating determinants of vessel accident oil-spillage, where one of the hypothesized determinants is type of vessel (including both oil-cargo and non-oil-cargo vessels). Tobit regression estimates of vessel accident oil-spillage functions suggest that tank barges have incurred greater in-water and out-of-water oil-spillage for the post OPA-90 period than non-oil-cargo vessels; alternatively, tankers have not incurred greater out-of-water (in-water) oil-spillage than non-oil-cargo vessels (except for freight ships). The policy implication is that greater attention needs to be given to reducing tank barge accident oil-spillage in the post OPA-90 period. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

A vessel may spill oil intentionally or accidentally. Intentional spillage is typically operational dumping, e.g., after discharging its oil cargo, a vessel takes ballast water into its cargo tanks to ensure stability on the return trip, but then dumps the dirty ballast, water-in-oil mixture, on or before arrival at the loading port. [1] Accidental spillage may occur during the transfer of oil or from a vessel accident.

US public concern for oil-spillage from vessel accidents has intensified since the tanker vessel, the Exxon Valdez, ran aground in Alaska in March 1989, spilling nearly 11 million gallons of oil

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[1] This type of oil pollution by tankers has been investigated by Burrows et al. (1974).

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into Prince William Sound. [2] Subsequently, the US Congress passed the Oil Pollution Act of 1990 (OPA-90), establishing accountability for vessel oil spills. The liability of the vessel owner could be as high as US$1200 per vessel gross ton or US$10 million for vessels over 3000 gross tons, whichever is greater. [3] Limited liability may be lifted in a number of circumstances, such as gross negligence, willful misconduct, or violation of a safety regulation. The Act not only allows for federal unlimited liability but also for state- and local-government and private-interest unlimited liability. OPA-90 also mandates double hulls for tankers and tank barges traveling in US waters by the year 2015 – the assumption being that double hulls would reduce the vessel damage severity of an accident which, in turn, would reduce the oil-spillage of the accident. [4]

In December 1999 the single-hull tanker vessel, the Erika, sank in the Bay of Biscay, spilling 8000 tons of fuel oil on French beaches. In response to this spillage and as part of their campaign to reduce water pollution, the transport ministers of the European Union have called for a world-wide phasing out of single-hull tankers by 2012. The phasing-out would be done in steps based upon tanker age and size.

Several studies have investigated determinants of the vessel accident oil-spillage of oil-cargo vessels. Oil-spillage from a tanker accident is greater when the tanker is adrift and when the accident occurs in a coastal waterway, but less for larger and US flag tankers (Anderson and Talley, 1995). Tanker accident oil-spillage per vessel gross ton is less for a US flag tanker, but increases with the vessel damage severity of the accident (Talley, 1999). Regarding tank barge accidents, oil-spillage is greater for collision and material/equipment failure accidents (Anderson and Talley, 1995) and greater if the accident occurs in a river, at night time and for older barges, but less if precipitation exists at the time of the accident (Talley, 2000).

The focus of OPA-90 in reducing vessel accident oil-spillage is to reduce spillages of oil-cargo vessels, tankers and tank barges. The literature in investigating determinants of vessel accident oil-spillage has also focused on oil-cargo vessels. The rationale for this focus is that oil-cargo vessels are expected to spill more oil when involved in an accident than other (i.e., non-oil-cargo) vessels which just carry oil in their fuel tanks. The purpose of this study is to investigate the validity of the assumption that oil-cargo vessel accidents spill more oil than non-oil-cargo vessel accidents for the post OPA-90 period. Specifically, determinants of vessel accident oil-spillage are investigated, where one of the hypothesized determinants is type of vessel (including both oil-cargo and non-oil-cargo vessels).

[2] Subsequently, Exxon has been billed for more than US$3billion in cleanup expenses and may even owe more in damage claims following a 1994 liability trial.

[3] Estimates of the cleanup costs per ton of vessel oil spilled range US$1500–US$38,000 (Hopkins, 1992), whereas estimates of remaining environmental costs range US$1500–US$10,500 per ton (National Research Council, 1991). For an estimate of the economic impact of the 1989 Exxon Valdez oil spill on south-central Alaska's fisheries, see Cohen (1995).

[4] The cost effectiveness of OPA-90's double-hull requirement for reducing vessel accident oil-spillage has been questioned. Hopkins (1992) concludes that "costs appear substantial relative to benefits, and lawmakers' emphasis on design standards deflects attention from alternative risk reduction strategies – e.g., operation and maintenance measures – that warrant equal attention." Brown and Savage (1996) found that the expected benefits of reduced tanker spillage from the double-hull requirement are only 20% of the increased construction and operation costs of double-hulled tankers. In addition, Jin et al. (1994) found that electronic charts may be a far more cost-effective approach than double hulls for marine pollution control. For further discussion of OPA-90, see Wood (1995).

This study differs from previous studies investigating determinants of vessel accident oil-spillage by: (1) considering oil-spillages of both oil-cargo and non-oil-cargo vessels; (2) utilizing just post OPA-90 vessel accident data; and (3) distinguishing between in-water and out-of-water spillages. The latter may occur on-board the vessel or land side, e.g., during fueling. Oil-spillage functions are estimated for both types of spillages, utilizing tobit regression analysis and detailed data of individual vessel accidents that were investigated by the US Coast Guard during the five-year time period 1991–95 (post OPA-90).

2. The model

The oil-spillage of a vessel involved in an accident is posited to be a function of the type of vessel, type of accident, vessel characteristics, phase of vessel operation, weather/visibility characteristics, and type of waterway. Type of vessel includes both oil-cargo and non-oil-cargo (commercial and non-commercial) vessels. Oil-cargo vessels include tank barge (TANKBARGE) and tanker (TANKSHIP); non-oil-cargo commercial vessels include fishing boat (FISHBOAT), passenger boat (PASSBOAT), and freight ship (FRTSHIP); and recreational boat (RECREBOAT) is a non-commercial vessel. A positive relationship is expected (via the literature) between vessel-accident oil-spillage and oil-cargo vessels, tank barges and tankers. It is unclear which, if any, non-oil-cargo vessel will have a greater oil-spillage subsequent to an accident, ceteris paribus.

The type of accident includes a sinking (SINKING), a grounding (GROUNDING), a flooding (FLOODING), an equipment failure (EQUIPFAIL), a structural failure (STRUCFAIL), a collision (COLLISION), a fire (FIRE), an explosion (EXPLOSION), or a capsizing (CAPSIZING). [5] For non-oil-cargo vessels, greater oil-spillage is expected in an explosion than in a grounding accident, since the former is expected to result in greater vessel damage than the latter. For oil-cargo vessels, greater oil-spillage is expected in a grounding than in a collision accident, since the former is more likely to result in a hull rupture than the latter. The relationship between oil-spillage and a structural failure is less clear. Significant oil spills have resulted from tank barge structural hull failures, due to the "buckling" phenomenon, which is attributed to loading/unloading and/or the distribution of oil cargo within the vessel. If the vessel is a tank barge and a buckling structural failure occurs, a positive relationship is expected between oil-spillage and STRUCFAIL. [6] The relationships between oil spillage and the remaining types of accidents are unclear.

[5] A ship accident may be a: (1) collision – vessel struck or was struck by another vessel on the water surface, or struck a stationary object, not another ship (an allision); (2) grounding – vessel is in contact with the sea bottom or a bottom obstacle, struck object on the sea floor, or struck or touched the bottom; (3) fire and/or explosion – the fire and/or explosion is the initiating event reported, except where the first event is a hull/machinery failure leading to the fire/explosion; (4) an equipment failure (or structured-machinery-other) – hull/machinery damage, missing, and miscellaneous non-classified reasons (e.g., vessels sunk due to either weather or break-up related to causes not covered by other casualty categories); or (5) three other types of accidents that are self-explanatory – sinking (foundering and swamping), flooding (without sinking), and capsizing.

[6] A discussion of the "buckling" phenomenon is found in Nadeau (1998).

Vessel characteristics include vessel age, size and flag. Since vessel structural failure is expected to increase with age, the a priori sign of the relationship between vessel age (VAGE) and accident oil-spillage is positive. The relationship with respect to vessel size (VSIZE) is unclear. On one hand, larger vessels are expected to sustain less damage in collisions and therefore spill less oil, but on the other hand, are expected to sustain greater damage and spill more oil in explosions and structural failures than smaller vessels. Alternatively, larger vessels are less susceptible to hazardous weather and waterway conditions, i.e., more seaworthy, and thus less likely to spill oil given these adverse conditions.

The US is a nation that has some of the highest maritime safety standards in the world (Gracey, 1985). The variation in maritime safety standards among countries is measured by whether a ship flies a US flag (USFLAG) or a non-US flag. Since higher safety standards are expected to be negatively correlated with vessel accident oil-spillage, a negative relationship is expected between USFLAG and oil-spillage.

The phase of vessel operation is described by whether the vessel was underway (UNDERWAY), moored or docked (MOORDOCK), towed (TOWED), anchored (ANCHORED) or adrift at the time of the accident. For collisions and groundings, the a priori sign of the relationship between UNDERWAY and oil-spillage is positive – as speed increases, greater the force of impact and greater should be the amount of oil-spillage. The relationships between oil-spillage and the vessel operations, MOORDOCK, TOWED and ANCHORED, are unclear.

Weather/visibility characteristics include cold weather (COLD), high winds (HIGHWINDS), precipitation (PRECIPTN), and whether the accident occurred at nighttime (NIGHT) versus daytime and if the visibility was poor (POORVISIB). Although adverse weather and visibility conditions are likely to increase the risk of oil-spillage, [7] their impact on the amount of oil-spillage is unclear.

Type of waterway is described as either a coastal waterway (COAST), ocean (OCEAN), river (RIVER), harbor (HARBOR), or lake or bay. For collisions and groundings, it is likely that oil-spillage will be less in a harbor than in open waterways, since vessel speed is often lower in the former than in the latter, thereby reducing the likelihood of an oil spillage; otherwise the relationship between type of waterway and oil spillage is unclear. Finally, vessel accident in-water gallons of oil spillage (IWATSP) are distinguished from out-of-water gallons of oil spillage (OWATSP).

3. Data and empirical results

Vessel accident in-water and out-of-water oil-spillage functions are estimated utilizing detailed data of individual vessel accidents that were investigated by the US Coast Guard during the five-year time period 1991–95 (i.e., post OPA-90). The data were extracted from the US

[7] Precipitation may also have a positive lagged effect on the risk of oil-spillage, e.g., resulting in fast currents and high waters that increase this risk.

Table 1
Variable definition and descriptive statistics

	Measurement	Mean (S.D.)
Dependent variables		
In-water oil-spillage, IWATSP	gallons	1745 (27059)
Out-of-water oil-spillage, OWATSP	gallons	18.1 (207)
Explanatory variables		
Type of vessel		
TANKBARGE	1 if a tank barge, 0 otherwise	0.115 (0.319)
TANKSHIP	1 if a tank ship, 0 otherwise	0.041 (0.197)
FISHBOAT	1 if a fishing boat, 0 otherwise	0.422 (0.494)
PASSBOAT	1 if a passenger boat, 0 otherwise	0.053 (0.225)
FRTSHIP	1 if a freight ship, 0 otherwise	0.057 (0.232)
RECREBOAT	1 if a recreational boat, 0 otherwise	0.138 (0.345)
Type of accident		
SINKING	1 if a sinking, 0 otherwise	0.407 (0.492)
GROUNDING	1 if a grounding, 0 otherwise	0.234 (0.424)
FLOODING	1 if a flooding, 0 otherwise	0.045 (0.208)
EQUIPFAIL	1 if an equipment failure, 0 otherwise	0.046 (0.210)
STRUCFAIL	1 if a structural failure, 0 otherwise	0.021 (0.143)
COLLISION	1 if a collision, 0 otherwise	0.046 (0.210)
FIRE	1 if a fire, 0 otherwise	0.041 (0.197)
EXPLOSION	1 if an explosion, 0 otherwise	0.028 (0.165)
CAPSIZING	1 if a capsizing, 0 otherwise	0.023 (0.151)
Vessel characteristics		
Age, VAGE	years	25.0 (16.4)
Size, VSIZE	gross tons	2938 (10182)
US flag, USFLAG	1 if a US flag, 0 otherwise	0.882 (0.323)
Vessel operation phase		
UNDERWAY	1 if vessel is underway, 0 otherwise	0.389 (0.482)
MOORDOCK	1 if vessel is moored or docked, 0 otherwise	0.334 (0.472)
TOWED	1 if vessel is towed, 0 otherwise	0.057 (0.232)
ANCHORED	1 if vessel is anchored, 0 otherwise	0.049 (0.215)
Weather/visibility characteristics		
COLD	1 if cold temperature (less than 32 Fahrenheit degrees), 0 otherwise	0.875 (0.331)
HIGHWINDS	1 if high winds exist (greater than 20 knots), 0 otherwise	0.078 (0.268)
PRECIPTN	1 if precipitation weather, 0 otherwise	0.043 (0.205)
NIGHT	1 if nighttime, 0 otherwise	0.068 (0.253)
POORVISIB	1 if visibility is poor, 0 otherwise	0.915 (0.279)
Type of waterway		
COAST	1 if accident occurred in a coastal waterway, 0 otherwise	0.314 (0.465)
OCEAN	1 if accident occurred in an ocean, 0 otherwise	0.099 (0.298)

Table 1 (Continued)

	Measurement	Mean (S.D.)
RIVER	1 if accident occurred in a river, 0 otherwise	0.235 (0.425)
HARBOR	1 if accident occurred in a harbor, 0 otherwise	0.034 (0.180)

Coast Guard Marine Safety Management System (MSMS) database. [8] Variables used in the estimations, their specific measurements and descriptive statistics (mean and S.D.) appear in Table 1.

Given that a vessel accident does not necessarily result in an oil-spillage, some of the observations of the dependent variables, IWATSP and OWATSP, may be zero. That is, the distributions of these variables are left-censored. If their equations were estimated using ordinary least squares, a statistical technique that ignores censoring, the parameter estimates may be biased. We prevent such bias by utilizing the statistical technique, tobit regression analysis, [9] which explicitly accounts for censored dependent variables. Also, possible estimation bias from omission of relevant explanatory variables is addressed by considering annual time trend and binary variables in our estimations.

Table 2 reports tobit regression estimates of vessel accident in-water and out-of-water oil-spillage functions. The estimates include statistically significant explanatory variables, constant terms and an annual time trend variable YEAR. Focusing initially upon the IWATSP results, we see that the function fits the data well. The likelihood ratio statistic is 33.8, well above the 15.1 critical value for significance at the 0.01 level. The results suggest that vessel accident in-water oil-spillage for the post OPA-90 period is greater for a tank barge than for non-oil-cargo vessels, while the spillage for a tanker is not greater than that of non-oil-cargo vessels except for a freight ship. Further, the spillage is less for US flag vessels but greater when the vessel is moored or docked than when underway, towed, anchored or adrift.

Among weather/visibility characteristics, we see that vessel accident in-water oil-spillage is less when poor visibility exists, all else held constant. The negative coefficient for POORVISIB is initially surprising, since one might expect poor visibility to result in greater oil-spillage when a vessel accident occurs. However, the negative coefficient may suggest offsetting behavior by vessel operators. [10] Specifically, it may suggest that poor visibility produces

[8] Five MSMS data tables were merged to obtain the data set for this study. The five data tables include: the Marine Casualty and Pollution Master Table (cirt), the Marine Casualty Vessel Supplement Table (civt), the Vessel Identification Table (vidt), the Marine Casualty Weather Supplement Record (cwxt), and the Marine Pollution Substance Table (cpdt).

[9] For a discussion of tobit regression analysis, see Greene (1997).

[10] The offsetting behavior hypothesis has been used to explain the impacts of safety regulations. Specifically, the offsetting behavior hypothesis recognizes that safety regulation may affect the allocation of resources by increasing the frequency of safety diminishing behavior. The hypothesis was initially discussed by Lave and Weber (1970) but then advanced by Peltzman (1975).

Table 2
Vessel accident oil-spillage: Tobit regression estimates

Variable	IWATSP coefficient (*t*-statistic)	OWATSP coefficient (*t*-statistic)	IWATSPT coefficient (*t*-statistic)	OWATSPT coefficient (*t*-statistic)
Type of vessel				
TANKBARGE	6519 (1.82)	429 (2.27)	−3.30 (−1.76)	3.78 (2.20)
FRTSHIP	−16164 (−2.76)	–	−9.74 (−3.43)	–
TANKSHIP	–	–	−7.78 (−2.59)	–
Type of accident				
SINKING	–	−582 (−2.52)	–	–
EQUIPFAIL	–	1043 (4.28)	–	9.97 (4.18)
Vessel characteristics				
USFLAG	−7070 (−1.81)	–	–	–
Vessel operation phase				
MOORDOCK	5315 (2.25)	–	–	–
Weather/visibility characteristics				
HIGHWINDS	–	654 (2.35)	–	5.82 (2.49)
POORVISIB	−16516 (−3.93)	–	−10.74 (−4.77)	–
Miscellaneous variables				
YEAR	–	−161 (−2.07)	–	−1.23 (−1.62)
Constant	14469 (2.77)	13455 (1.86)	11.47 (5.19)	99.85 (1.42)
# Observations	862	639	603	457
Likelihood ratio test statistic	33.8	52.1	38.0	34.2

oil-spillage-reduction enhancing behavior by vessel operators which more than offsets any increase in oil-spillage attributable to poor visibility, all else held constant. Alternatively, the negative coefficient may reflect operating constraints that poor visibility imposes on vessel operators.

As for the IWATSP model, the OWATSP model fits the data well – the likelihood ratio statistic is large and statistically significant at the 0.01 level. The estimation results suggest that tank barge accidents have incurred greater out-of-water oil-spillage for the post OPA-90 period than other vessel (including tanker) accidents. Further, the spillage for a tanker accident is not greater than that of non-oil-cargo vessel accidents. Unlike the IWATSP model, the results suggest that out-of-water oil-spillage is less for a sinking accident but greater for an equipment failure than for other types of vessel accidents, all else held constant. The results also suggest that vessel accident out-of-water oil-spillage is greater when high winds exist. The negative coefficient for the annual time trend variable YEAR suggests that vessel accident out-of-water oil-spillage declined over the time period of the study.

Further insight into the impact of vessel type on vessel accident oil spillage may be gained by normalizing oil-spillage for vessel size and re-estimating. In Table 2, tobit regression estimates are also found for the dependent variables, vessel accident in-water and out-of-water oil spillage per vessel gross ton, IWATSPT and OWATSPT. The results suggest that vessel accident in-water oil-spillage per vessel gross ton for the post OPA-90 period is less for oil-cargo vessels (tank barges and tankers) than for non-oil-cargo vessels except for a freight ship. These results initially appear to be inconsistent with the IWATSP results. However, when the type-of-vessel coefficients are compared, the results are consistent. Specifically, the IWATSPT results indicate that in-water oil-spillage per vessel gross ton for a tank barge is greater than that of a tanker and the spillage for a tanker is greater than that of a freight ship. Since these vessels are generally larger than the other types of vessels in our data and given their negative coefficients, the results also suggest that larger vessels incur less in-water oil spillage per vessel gross ton than smaller vessels. The OWATSPT results suggest that tank barge accidents have incurred greater out-of-water oil spillage per vessel gross ton for the post OPA-90 period than other vessel (including tanker) accidents, again consistent with the OWATSP results.

4. Adjusted tobit coefficients

Tobit regression, unlike ordinary least squares, coefficients do not measure the correct change in a dependent variable from a change in an explanatory variable for non-zero observations of the dependent variable. However, tobit coefficients can be adjusted to obtain such measures. McDonald and Moffitt (1980) show that the change in the dependent variable (for its observations above a limit such as zero) from a change in an explanatory variable can be measured as the product of the explanatory variable's tobit coefficient and the adjustment factor "A":

$$A = \{1 - [zf(z)/F(z)] - [f(z)^2/F(z)^2]\},$$

where z represents an evaluation (at the means of the explanatory variables) of the tobit equation divided by the equation's standard error; $f(z)$ is the unit normal density; and $F(z)$ is the cumulative normal distribution function. We refer to the product of "A" and a given tobit coefficient as the latter's "adjusted tobit coefficient".

The adjusted tobit coefficients which correspond to the tobit coefficients in Table 2 are presented in Table 3. The IWATSP coefficients indicate that a tank barge when involved in an accident spills 2810 more in-water gallons of oil than other vessels and a moored or docked vessel spills 2291 more gallons than when underway, towed, anchored or adrift. A freight ship accident spills 6968 fewer in-water gallons of oil than other vessels. When poor visibility exists, a vessel accident spills 7119 fewer gallons and a US flag vessel spills 3048 fewer gallons, all else held constant.

The OWATSP adjusted tobit coefficients indicate that a tank barge accident spills 16.4 more out-of-water gallons of oil than other type-of-vessel accidents. An equipment failure accident spills 39.8 more gallons than other accidents except for sinking accidents and if high winds exist, the vessel accident spills 25.0 more gallons of oil, all else held constant. A sinking vessel accident spills 22.2 fewer gallons of oil than other types of accidents (except for equipment failure). For the time period of the study, vessel accident out-of-water oil-spillage declined 6.16 gallons per year.

Table 3
Vessel accident oil-spillage: Adjusted tobit coefficients

Variable	IWATSP	OWATSP	IWATSPT	OWATSPT
Type of vessel				
TANKBARGE	2810	16.4	−1.65	0.20
FRTSHIP	−6968	–	−4.88	–
TANKSHIP	–	–	−3.90	–
Type of accident				
SINKING	–	−22.2	–	–
EQUIPFAIL	–	39.8	–	0.52
Vessel characteristics				
USFLAG	−3048	–	–	–
Vessel operation phase				
MOORDOCK	2291	–	–	–
Weather/visibility characteristics				
HIGHWINDS	–	25.0	–	0.31
POORVISIB	−7119	–	−5.38	–
Miscellaneous variables				
YEAR	–	−6.16	–	−0.06
Constant	6237	513	5.75	5.26

A comparison of IWATSPT type-of-vessel adjusted tobit coefficients indicates that a freight ship spills 4.88, a tanker spills 3.90, and a tank barge spills 1.65 fewer in-water gallons of oil per vessel gross ton than other vessels. The OWATSPT tank barge adjusted tobit coefficient indicates that a tank barge spills 0.20 more out-of-water gallons of oil per vessel gross ton than other vessels.

5. Conclusion

The vessel accident oil-spillage literature has focused on spillages of oil-cargo vessels, tankers and tank barges, implicitly assuming that these vessels incur greater accident oil-spillage than other (i.e., non-oil-cargo) vessels which just carry oil in their fuel tanks. This study investigated the validity of this assumption for the post US OPA-90 period by investigating determinants of vessel accident oil spillage, where one of the hypothesized determinants is type of vessel (including both oil-cargo and non-oil-cargo vessels). Spillage functions were estimated, utilizing tobit regression analysis and detailed data of individual vessel accidents that were investigated by the US Coast Guard during the five-year time period 1991–95 (post OPA-90).

The results suggest that vessel accident in-water oil-spillage for the post OPA-90 period is greater for a tank barge than for non-oil-cargo vessels, while the spillage for a tanker is not greater than that of non-oil-cargo vessels except for a freight ship. For this period, tank barges also incurred, but not tankers, greater vessel accident out-of-water oil-spillage than non-oil-cargo vessels. In addition, tank barge accidents incurred greater in-water and out-of-water spillages than tanker accidents. The policy implication of these results for reducing vessel accident oil-spillage in the post OPA-90 period is clear – greater attention, e.g., regulation of barges, needs to be given to reducing the vessel accident oil-spillage of tank barges.

The estimation results also suggest that vessel accident in-water oil-spillage is less for a US flag vessel but greater when the vessel is moored or docked. Further, in-water oil-spillage is also less when poor visibility exists – which may suggest offsetting behavior, i.e., oil-spillage-reduction enhancing behavior by vessel operators, which more than offsets any increase in oil-spillage attributable to poor visibility, all else held constant. For vessel accident out-of-water oil-spillage, the results suggest that the spillage is less for a sinking but greater for an equipment failure accident than for other types of accidents and greater when high winds exist. Adjusted tobit coefficients indicate that a moored or docked vessel accident spills 2291 more in-water gallons of oil than when the vessel is underway, towed, anchored or adrift, while an equipment failure accident spills 39.8 more out-of-water gallons of oil than other types of accidents (except for a sinking), all else held constant.

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