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MMS 98-0021

Coastal Marine Institute

Environmental and Safety Risks of an Expanding Role for Independents on the Gulf of Mexico OCS

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Cooperative Agreement
Coastal Marine Institute
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ABSTRACT

Smaller independent oil producers are doing more of the exploration and production (E&P) of offshore oil and gas reserves in the Gulf of Mexico. Both industry and regulatory analysts have expressed concern that this trend will lead to more accidents. Our objective was to ascertain if there is an empirical justification for such fears. As the study progressed it also seemed appropriate to use our data to see if the Minerals Management Service's (MMS) safety and platform inspection programs have reduced the frequency or severity of accidents and spills in the Gulf.

Descriptive statistics and econometric techniques were used to study data on accidents and oil spills recorded in MMS's event file. We organized these data on an operator-by-operator basis. Comparisons were made between major petroleum companies and large and small independents. Regression models were then used to determine the relationship between accidents and spills and several hypothesized explanatory factors.

Statistical analysis of accidents and oil spills recorded in MMS's event file provide little evidence to support the apprehension that an expanded role by independents constitutes a new or heightened threat to worker safety and the marine environment. In fact, our analyses indicate that, on average, independents had a marginally better safety and environmental record than majors.

We have not attempted to formulate economic or behavioral models that would provide a theoretical foundation for hypotheses as to why independents appear to have fewer accidents and spills than majors. Nor have we attempted to determine if the overall frequency of accidents and spills is optimal or "correct" from either an economic, philosophical, or technical standpoint.

Our analysis is relevant to MMS policy and program planning only insofar as proposals for new policies or changes in policies are driven by the premise that a larger role for smaller, independent firms poses new or heightened risks to worker safety or the environment. However, it is evident from our econometric results that the aging of operating platforms, firm-specific effects, year-specific effects, and MMS's safety and inspection programs significantly, in a statistical sense, affect the risk of an accident or an oil spill during E&P operations. These findings may be helpful in MMS's ongoing efforts to develop standards for "re-qualifying" older platforms and for measuring the safety and environmental performance of OCS operators in order to target its inspection program on those operators most in need of improvement.

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EXECUTIVE SUMMARY

Smaller independent oil producers are doing more of the exploration and production (E&P) of offshore oil and gas reserves in the Gulf of Mexico. Both industry and regulatory analysts have expressed concern that this trend will increase the risk of more accidents and oil spills in the Gulf. Our objective was to ascertain if there is an empirical justification for such apprehension. As the study progressed it also seemed appropriate and efficient to use our data to determine if the Minerals Management Service's (MMS) safety and platform inspection programs have reduced the frequency or severity of accidents or spills in the Gulf.

We used descriptive statistics and econometric techniques to study data on accidents and oil spills recorded in MMS's event file. These data were organized on an operator-by-operator basis. Regression models were then used to determine the relationship between the frequency and severity of accidents or spills and several hypothesized explanatory factors.

Our analyses of accidents and oil spills recorded in MMS's event file provide little statistical evidence to support the concern that an expanded role by independents in E&P activity constitutes a new or heightened threat to worker safety and the marine environment. In fact, our analyses uniformly suggest that on average independents had a marginally better safety record than majors.

Using the Tobit regression model to investigate the relationship between accidents or spills and various explanatory variables, we found that the age of an operator's platform and the number of INCs issued per MMS inspection of an operator's platforms were related to accidents or spills in a statistically significant way. This technique also enabled us to test for "unobserved" or unmeasured effects specific to firms or time periods.

We have not attempted to formulate economic or behavioral models that would provide a theoretical foundation for hypotheses as to why independents appear to have fewer accidents and spills than the majors. Nor have we attempted to determine if the overall frequency of accidents and spills is optimal or "correct" from either an economic, philosophical, or technical standpoint.

Our analysis is relevant to MMS policy and program planning largely insofar as proposals for new policies or changes in policies are driven by the premise that a larger role for smaller, independent firms poses new or heightened risks to worker safety or the environment. However, it is evident from our econometric results that the aging of operating platforms, firm-specific effects, year-specific effects, and MMS's safety and inspection programs significantly, in a statistical sense, affect the risk of an accident or an oil spill during E&P operation. These findings may be relevant for MMS's ongoing efforts to develop standards for "re-qualifying" older platforms and for measuring the safety and environmental records of individual operators in order to help MMS reach its goal of targeting its inspection and regulatory programs on operators most in need of improvement.

The study was limited to the 1987-1993 period because of extreme variation and possible discontinuities in the accident and oil spill data in MMS's event file prior to 1987. To us, these anomalies suggested classification or reporting changes that we were unable to account for or verify. Moreover, there are no data on MMS inspections and incidents of noncompliance (INCs) prior to 1986. Although this limitation in the study period was necessary because of time and budget constraints, accident rates in the Gulf were not only more stable in the post-1987 period but also an order of magnitude below their pre-1987 levels. In many respects, ascertaining the true magnitude and reasons for this remarkable post-1987 decline might be a more important study.

Descriptive statistics show that the nominal or un-weighted accident rate, measured as the number of accidents per million platform-hours, was as follows:

3.34 for majors,
3.01 for large independents, and
2.08 for small independents.

Similarly, a weighted accident rate which attempts to distinguish among accidents according to their severity--by weighting accidents without injuries as one, accidents with injuries as five and accidents with fatalities as twenty-five--was as follows:

8.00 for majors
5.35 for large independents, and
3.85 for small independents.

We also calculated each operator-category's weighted accident rate as a share of the industry total and divided that share by the category's share of total platform years. Hence, a value smaller than one means that the operator had a smaller share of weighted accidents than of platform years and *vice versa*. According to this measure, the ratio for majors was 1.22 compared with a ratio for independents of approximately 0.6.

The differences between majors and independents measured in spills rather than accidents were similar but more extreme. For example, relating reported spills to platform hours, we found the following:

Majors reported 255 barrels spilled per million platform hours, and
Independents reported 24 barrels spilled per million platform hours.

Using production as the basis for comparison, we found the following:

Majors reported 15 barrels spilled for each million barrels produced, while
Independents reported four barrels spilled per million barrels produced.

Accident rates may be a better indicator of performance than barrels spilled because many spills are very small and result in negligible effects in the marine environment. In fact, MMS recently increased the threshold size at which operators are required to report spills to MMS. Thus, the risks to the marine environment about which the public seems most concerned may be better measured by the accident rate since major, catastrophic spills are more likely to be the consequence of major accidents.

We believe that there are factors other than firm size and the degree of economic integration--the attributes that are usually used to classify majors and independents--that are likely to explain accident and spill rates. Unless such intervening factors are taken into account, the descriptive comparisons summarized above may be misleading.

For instance, some of the concern about more independents working on the offshore appears to rest, at least partially, on the belief that independents are entering the Gulf by buying older, more accident prone platforms from majors. The data indicate, however, that older platforms make up a much larger share of the majors' platforms than of the independents. Thus, if age of platforms is an important intervening factor, the apparently superior performance of independents may simply be a consequence of the younger, safer, platforms they operate. Accordingly, if we were to account for the effects of the age of platforms statistically, it might be that independents should be expected to have fewer accidents than they actually do, given the age of the platforms they operate.

Regression analysis is one way to estimate how much of the variation in the outcome or dependent variable can be explained by such intervening factors. Because of the nature of the distribution of data on accidents and spills among operators, we have relied on specialized Tobit regression techniques to measure and account for ("hold constant" is the term often used) intervening variables. The results using the Tobit model confirm our earlier descriptive analysis: Even with intervening influences "held constant," independents have a better record than majors over the study period.

Our regression equations indicated that the average age of an operator's platforms is an important intervening variable, as are our measures of MMS's platform inspection program and the proportion of drilling relative to production taking place on the platform. Similarly, all of the terms (except one) measuring the undefined events unique to specific years were statistically significant.

A final objective of the study was to test the "bad actor" hypothesis. This hypothesis postulates that a few "bad actors" with very poor safety and environmental records dominate and distort the safety and environmental statistics. When we put this hypothesis to a statistical test, we found a relatively small number of firms that were significantly different from the average according to traditional statistical criteria. Some of the firms we identified, however, operated a large number of platforms; thus, the influence of bad actors may exceed their numbers. However, when we excluded bad actors from our data set and re-estimated our regression equation, we found the same patterns in our results, which indicates that our statistical estimates were not dominated by undue influence from a few firms with poor records.

1. INTRODUCTION

The Gulf of Mexico Outer Continental Shelf (OCS) region is the single most important focal point of offshore oil and gas activity in the U.S. today. More offshore leasing, geological and geophysical surveys, exploration drilling, and development drilling occurs in this region than any other. In 1994 the region accounted for about one third of both the total U.S. crude oil and natural gas reserve additions. The region also accounted for a significant portion of the total U.S. petroleum production, 12.5 percent of the total domestic oil and natural gas liquids production, and more than 25 percent of domestic gas production (US DOE/EIA, 1995). With respect to domestic petroleum supply, 2.52 billion barrels of remaining recoverable oil (crude oil and condensate) reserves and 29.3 trillion cubic feet of recoverable natural gas reserves are estimated to lie in 743 proven active fields in the Gulf OCS region (Melancon et al, 1995).

The apparent refocusing of exploration and production (E&P) activities and investments abroad by majors and larger independents in the early 1990s and the resulting relatively larger role for smaller independents in domestic E&P activity led to pessimism about the prospects of the Gulf of Mexico OCS maintaining its role as an important domestic source of petroleum supply (Gachet, 1993 and Trench, 1994). Similarly, these concerns also led to fear--evident in both industry and regulatory circles--that an expanded role for smaller independents on the OCS would pose greater risks to worker safety and the marine environment.

The premise underlying such apprehension was that, as major oil companies shift their E&P investments abroad, relatively more domestic E&P would fall to smaller independent companies, which do not have the majors' technical, scientific, or regulatory skills. These concerns have augmented calls for more stringent environmental regulations such as those incorporated in the Oil Pollution Act of 1990.

Do these concerns about the expanded role for smaller independents on the OCS rest on objective facts or subjective impressions? Is there persuasive evidence that an expanded role of smaller independents on the OCS would:

1) hinder the pace or effectiveness of petroleum resource development and

2) pose greater environmental and safety risks?

Iledare et al. (1995) attempted to address the economic questions and found strong statistical evidence that independents have been as aggressive and efficient as the majors in their search for and development of petroleum resources on the Gulf of Mexico OCS.

As to whether the expanded role of smaller independents poses greater environmental and safety risks, very little systematic research has been undertaken to define and measure the environmental and safety records and performances of either individual operators or groups of operators on the OCS. Moreover, analyzing the safety and environmental performance of firms of different sizes presents a number of problems; the foremost of these is access to environmental and safety event and exposure data that are statistically consistent and complete.

Thus, the original motivation for this study was to attempt to construct a consistent and comparable environmental, safety, and exposure database and to use it to identify and analyze the safety and environmental performances of firms of different sizes operating on the Gulf of Mexico OCS. Although it was not an objective when the project was initially conceptualized and funded, we have also made a preliminary analysis of whether MMS's platform inspection program has reduced the frequency or severity of accidents on the OCS.

Arnold and Koszela (1990) and the Marine Board of the National Research Council (1990) had previously critiqued MMS's inspection and safety program. Neither, however, made or discussed operator-to-operator comparisons of safety or environmental performance.

After the analysis described in this report was completed and a draft submitted to MMS in the Fall of 1996, a Performance Measures Work Group composed of 29 representatives of oil and gas firms or associations and MMS staff was organized to create measures that ultimately could be used to distinguish and evaluate the performance of offshore operators (JBF Associates, 1997). Further, in the summer of 1997 MMS posted on its web site a draft strategic plan for the agency which included quantitative measures of safety and environmental performance of the offshore industry (MMS, 1997). Unfortunately, the measures and data in these two MMS efforts are not comparable with each other or with the measures we have used in this report; therefore, we have not tried to integrate them into our analysis.

The safety index articulated in MMS's draft strategic plan uses a weighting procedure similar to the one used in this report to reflect the severity of accidents. None of the ten measures developed by the Performance Measures Work Group attempts to distinguish among events according to the severity of their consequences; instead, an accident with multiple fatalities counts the same as an accident disrupting enough to stop work, but resulting in no injuries or fatalities.

A second difference is the data used to "normalize" comparisons. Lacking any hours-worked data, we used the number of major structures currently operating as drilling, production, or drilling and production facilities as a basis for making comparisons. The MMS/industry work group plans to use "major structures plus one half of the operator's minor structures" and/or (for some) the "number of wells spudded" to normalize. For other measures the work group will ask operators to generate "hours-worked" data to make comparisons, and for two other measures it will use the number of "components" housed on the platform inspected by MMS. A component is a line item inspected by MMS and is usually a distinct, separable, process such as a pump, a well, or a compressor. Such measures, the work group argues and we agree, are necessary to distinguish the degree of "complexity" inherent in each platform. MMS's draft strategic plan says it will use a measure reflecting the complexity of the operations it regulates to calculate its safety index, but gives no indication how this will be done.

MMS's draft strategic plan includes two environmental indicators for the agency, but both are based on improvements from a "baseline," with the baseline "to be determined." The performance work group uses oil spills and "exceedances" of EPA discharge limits as environmental performance indicators, both of which conceptually are similar to our measures. If we had known of the measures articulated by MMS's strategic plan or the industry/MMS work group before we completed our analysis, we would have analyzed how they might have changed our results. Unfortunately, we did not learn of them in time to do this.

This report is organized into five sections preceded by an executive summary. Following this Introduction (Section 1), Section 2 compares environmental and safety records of OCS operators by reviewing the types and causes of safety and environmental events and analyzing measurable effects of each event in terms of deaths and injuries sustained, lost time, pollution spills, and property damage.

Section 3 defines measurable indicators of operator performance such as nominal, weighted, and relative accident and spill rates. These rates are used to measure trends in safety and environmental performance of majors and independents in OCS E&P operations.

Section 4 explains our use of empirical models to examine the association between the risk of an accident or a pollution spill and several hypothesized explanatory variables, such as: the cumulative age of platforms operated, the distribution of platforms by type of operation and/or product (i.e., production, drilling/oil or gas), the effectiveness of regulation and its enforcement as captured by the number of inspections and instances of noncompliance, and firm-size dummy variables. The possible effects of these factors on accident rate and on the risks of accident in oil and gas E&P operations are evaluated using a panel data set of firms classified as majors and large and small independents over the period 1987-1993 to estimate the Tobit model of accident and spill rates of accidents or spills.

The section also describes an attempt to use weighted least squares regression analysis to evaluate the impact of "bad actors" (firms with significantly worse than average accident and spill records) on the industry-wide statistics.

Section 5 summarizes our principal findings and conclusions.

2. COMPARING ENVIRONMENTAL AND SAFETY RECORDS OF MAJORS AND INDEPENDENTS OPERATING ON THE GULF OF MEXICO OCS

A serious obstacle to the analysis of offshore safety performance has been reliable data. To date, no comprehensive, consistent, and accessible database on operator-specific safety and environmental performance is available. Thus, a part of our research entailed constructing a consistent data set from which meaningful comparisons of the relative safety and environmental performance of firms of different sizes could be made.

2.1 - Data

The primary sources of information used in this report are the MMS events and platform inspection files. The events file contains narrative and numerical information on unplanned or unexpected incidents relating to: 1) environmental damage or upset; 2) workplace accidents resulting in bodily injury, illness, disease, or death. Accidents are also characterized by cause, e.g., loss of well control, spills, fires, explosions, loss of structure, and collision. Comparable data on violations of operating orders (recorded as incidents of noncompliance of\r "INCs") are available from MMS platform inspection data system.

Both of these files were made available to Louisiana State University's Center for Energy Studies through an electronic medium. The data were organized into a panel data set by firm-size--majors, smaller independents, and large independents--for the period 1980 through 1994. Subsequently, we processed the data to characterize the causes and effects of environmental and safety "events."

One serious limitation of MMS's events file is the lack of a congruent data series on man-hours worked on the Gulf OCS. Without such data, conventional accident rates, usually measured per 100 full-time equivalent workers, cannot be computed. As a consequence, we have created alternative exposure data series using the number of operating platforms, the quantity of petroleum produced, or the number of wells drilled as proxies for calculating performance indicators such as accident, fatality, or spill rates.

A second limitation was the inherent "lumpiness" or irregularity of much of the accident and oil spill data. Accidents are rare events in the offshore industry, especially in the 1987 to 1993 period. Many operators reported no accidents during the individual years included in the study period. Similarly, oil spills are rare events relative to the total volume of petroleum produced. Over the period of our study, for example, the total number of barrels produced on the Gulf OCS was 1.8 billion. The total number of barrels reported as spilled was 34,000 or 0.000034 billion. Moreover, one or two "large" spills quantitatively distort the data during the period. Thus, in the regression analysis reported on in Section 4, we employed the Tobit modeling method to deal with some of the statistical problems created by our inherently "lumpy" data.

2.2 - Classifying Majors and Independents

For analytical purposes, oil and gas operators operating on the Gulf of Mexico OCS in the U.S. have been classified into three groups--majors, large independents, and smaller independents. Definitions of these groups vary among different sources of information, but we have used the following definitions, which will be carried throughout the study unless otherwise indicated:

- Majors are integrated companies with more than 1 billion BOE in petroleum reserves worldwide. They are engaged in several stages of exploration, production, transportation, refining, and marketing of oil and gas worldwide.

- Large independents are those firms cited in the Oil and Gas Journal (OGJ) list of the largest 100 firms that are not majors but have assets of at least $500 million. In addition, for analytical purposes, we have included in this category subsidiaries of large foreign companies such as Agip Petroleum, Elf Aquaitaine, and Nippon Oil Company, even if their U.S. operations do not satisfy this criterion.

- Smaller independent firms are those appearing on the OGJ list of the largest 300 firms that do not have assets of $500 million or more. Data on assets are only available for publicly traded companies. Thus, our definition, by default, classifies all privately held companies as "smaller independents." However, we contacted several such privately held companies, and each said "smaller independent" was the appropriate designation (see Pulsipher et al. (1996) for a list of firms included in each category).

2.3 - Environmental and Safety Events and Risks on the OCS

The sharp fluctuation of accidents reported for all operators over the period from 1980 through 1994 is illustrated in Figure 1. At the crest of the domestic oil boom in the early 1980's, recorded accidents soared when, in expectation of $50/barrel-oil-forever, 200 or more new platforms were being installed annually on the OCS (with inexperienced workers on rush schedules). The total number of accidents jumped from about 120 in 1980 to an annual average of 450 between 1982 and 1985. When the world oil price dropped, so did OCS activity and so did OCS accidents--with the industry's total accidents falling from 475 in 1985 to fewer than 150 in 1986.

After the drop, however, offshore accidents remained at, relatively, very low levels even after OCS activity revived in the late 1980's and early 1990's. As can be seen in Figure 1, there is nearly an order of magnitude difference between the accident-scarred, early 1980's and the post-price-collapse period--despite, as measured on the left axis, a steadily growing number of operating platforms. It is difficult to attribute a change of this magnitude solely to changes in activity levels. Changes in reporting format and requirements and new definitions of standards have been suggested by Arnold and Koszela (1990) as possible reasons for the change, but not measured. Other possible explanations are the initiation of MMS's inspection program and a greatly increased emphasis on safety by the platform operators.

We were unable to sort out these factors within the budget available for this project; therefore, we chose to limit our analysis to the 1987-1993 period, where the variation of accidents and spills from year-to-year appears more reasonable and for which we have data on inspections and incidents of noncompliance (INC). Admittedly, explaining the dramatic drop between the two periods might be a more important exercise, but the project we agreed to undertake was to examine differences among majors and independents, not to explain industry-wide trends.

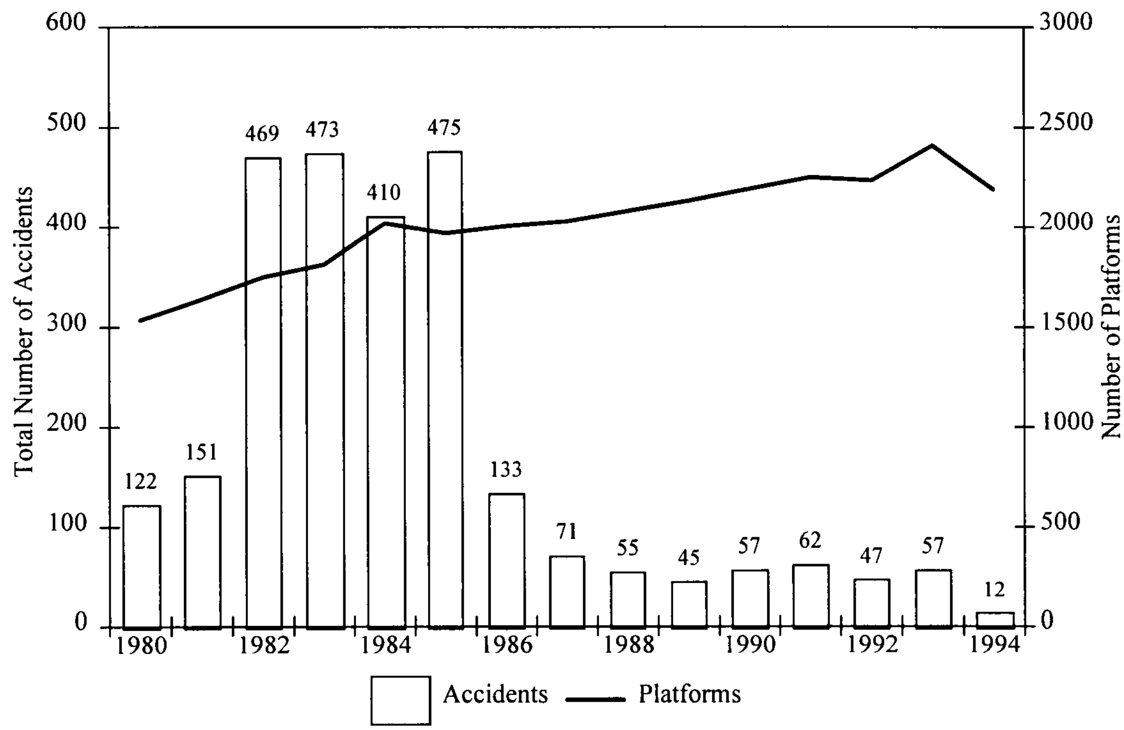

Figure 1. Total Number of Accidents Compared with Number of Operating Platforms, 1980-1994.

Table 1 presents the data on accidents during E&P operations for oil and gas firms on the OCS for the period 1987-1993. The data are organized by firm size and displayed by the activity underway--drilling operations, completions and workovers, production, and "other," which includes abandonment, pipelines, and installations.

Table 2 is a percentage breakdown of Table 1. Over the seven-year period, more than two out of three accidents reported in the MMS event files occurred during production operations; 18.3 percent occurred during drilling-related operations; completions and workover operations accounted for the remaining 3.2 percent. The majors accounted for approximately 70 percent of the total accidents reported during E&P operations on the OCS for the period 1987-1993.

2.3.1 - Causes of Accidents on the OCS: Table 3 (see page 13) categorizes the recorded causes of accidents, in percentages of total accidents, allocated among the majors and large and small independents. It shows that MMS attributed nearly 56 percent of all accidents to drilling, wellhead, or production system failures, with production system failures alone accounting for about 42 percent. This is somewhat surprising since the prevailing opinion is that most offshore accidents are largely attributable to "human factors" rather than equipment failures (Arnold and Koszela, 1990 and Marine Board, 1990).

Table 1

Environmental and Safety Accidents During E&P Operations
on the Gulf of Mexico OCS, 1987-1993

		Independents			Total
Operation	Majors	Small	Large	Total	OCS
Drilling	44	12	19	31	75
Production	202	30	47	77	279
Completion/Workover	8	4	1	5	13
Other	33	1	10	11	44
Total	287	47	77	124	411

Table 2

Percent Distribution of Accidents During E&P Operations
on the Gulf of Mexico OCS, 1987-1993

		Independents			Total
Operation	Majors	Small	Large	Total	OCS
Drilling	10.7	2.9	4.6	7.5	18.3
Production	49.1	7.3	11.4	18.7	67.9
Completion/Workover	2.0	0.9	0.2	1.2	3.2
Other	8.0	0.2	2.4	2.6	10.6
Total	69.8	11.6	18.7	30.2	100.0

Table 3

Percent Distribution of Environmental and Safety Accidents on the Gulf of Mexico OCS by Primary Cause, 1987-1993

Cause	Majors	Independents			Total
		Small	Large	Total	OCS
Drilling Systems Failure	5.6	1.0	2.53	3.5	9.1
Wellhead Systems Failure	3.5	0.5	0.76	1.3	4.8
Production Systems Failure	27.6	5.6	8.61	14.2	41.8
Human Error of Judgment	7.6	1.8	1.77	3.5	11.1
Unspecified	2.0	0.3	0.00	0.3	2.3
Miscellaneous Equipment	5.1	0.8	1.52	2.3	7.3
Other	18.2	1.8	3.54	5.3	23.5
Total	69.6	11.7	18.7	30.4	100.0

Differences in definitions, data, and time periods may all be at work. Arnold and Koszela (1990), for example, uses "fires and explosions" as opposed to total accidents, as well as using somewhat earlier data. Furthermore, when we categorized the 1980-1986 data using the same breakdown as in Table 3, we found that the percentage of total accidents attributable to "human error or judgment" was about 20 percent as opposed to the 11 percent shown in Table 3 for the 1987-1993 period.

Figure 2 depicts the percentage of total accidents for each group of operators accounted for by human error in the 1987-1993 period. Although the relative proportions for majors and independents (considered as a group) are roughly the same, a larger proportion of accidents reported by smaller independents was attributed to human error.

2.3.2 - Measurable Effects of Accidents on the OCS: The severity of accidents can be measured in terms of the number of injuries or deaths of employees, the amount of damage to property, the loss of time during E&P operations, or the quantity of oil spilled. Table 4 presents the distribution of accidents, injuries, fatalities, and spills for the three categories of firms. Although the number of injuries is roughly proportional to the number of accidents for the majors and independents considered as a groups, over 90 percent of the fatalities and spills were attributable to the majors.

Table 5 presents total environmental and safety incidents for firms of different sizes and by type for the period 1987-1993. Most of the measures show roughly proportionate divisions between majors and independents. However, independents show a much larger share of blowouts as well as a slightly larger share of injuries than would be proportionate to their numbers. Conversely, as discussed earlier, majors had a disproportionate share of fatalities during the period.

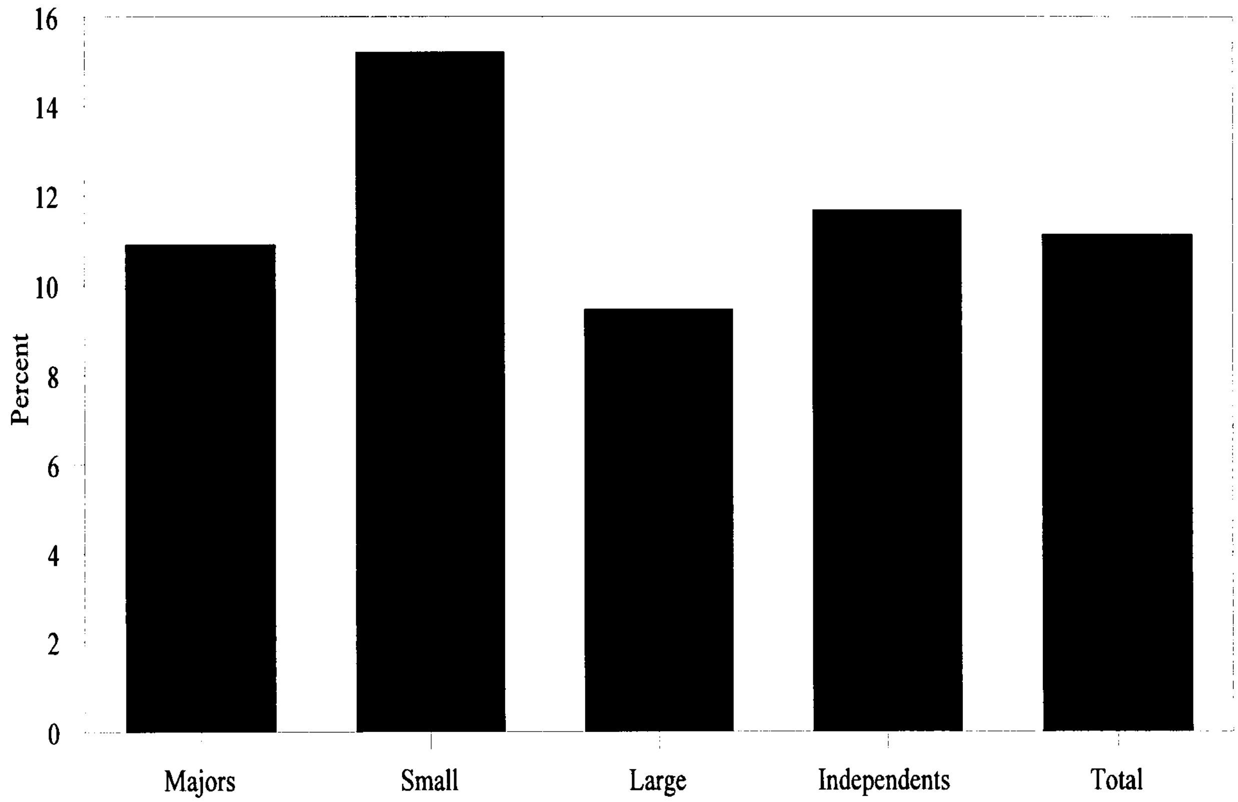

Figure 2. Proportion of Environmental and Safety Accidents Accounted for by Human Errors by Size of Firm, 1987-1993.

Table 4

Measurable Effects of Accidents on the Gulf of Mexico OCS, 1987-1993

	Majors		Independents						Total	
			Small		Large		Total		OCS	
Effect	#	%	#	%	#	%	#	%	#	%
Number of Accidents	287	69.8	47	11.4	77	18.7	124	30.2	411	100.0
Number of Injuries	41	66.1	10	16.1	11	17.7	21	33.9	62	100.0
Number of Fatalities	17	94.4	0	0.0	1	5.6	1	5.6	18	100.0
Volume of Spills (bbl)	21,954	95.1	457	2.0	683	3.0	1,140	4.9	23,094	100.0

Table 5

Type of Environmental and Safety Incidents on the Gulf of Mexico OCS, 1987-1993

		Independents			Total
Type	Majors	Small	Large	Total	OCS
Blowout	9	7	8	15	24
Injury	19	7	8	15	34
Fatality	12	0	1	1	13
Fire	101	10	23	33	134
Explosion	7	2	0	2	9
Spill	134	19	33	52	186
Other	7	1	3	4	11
Total	289	46	76	122	411

3. SAFETY AND ENVIRONMENTAL PERFORMANCE IN EXPLORATION AND PRODUCTION OPERATIONS

Aggregated accident and spill data alone have limited analytic value. The wide variety of hazards encountered in E&P operations, the severity of the damages incurred, and the number and type (as well as conduct) of operators involved in accidents may make such data misleading. Differences in the scale of the activity that creates the potential for accidents (e.g., the volume of production, the number of wells drilled, the number of platforms operated, etc.) must be accounted for in order to make meaningful comparisons among operators. We refer to these measures as dimensions of exposure. Similarly, measures that reflect the severity of damages incurred are needed. Otherwise, a quickly extinguished compressor fire may be implicitly equated with a serious accident with injuries, fatalities, and/or significant environmental pollution.

3.1 - Safety and Environmental Performance Indicators

For a comparative analysis of the relative safety performance of firms of different sizes, we distinguished between two broad measures of safety and environmental performance--nominal and weighted accident rates.

Traditionally, analysts of accidents and safety trends in the workplace have used measures such as incidents per 100 full-time employees for total recorded incidents, total lost-workday accidents, accidents involving days away from work and deaths, non-fatal accidents without lost workdays, or total lost workdays (Curlington, 1986).

Unfortunately, no data on labor force, man-hours worked, or time lost due to accidents are available either for OCS operations as a whole, for majors and independents, or for individual operators. Arnold and Koszela (1990) made estimates of total offshore employment that ranged between 15,000 and 20,000 total workers per year, but only for the period 1982-1985. Without hours worked on an operator by operator basis, we used proxy exposure data, the number of platforms operated per year in our analysis.

3.1.1 - Nominal Accident Rate (NAR): The nominal accident rate (NAR) is defined as the ratio of reported accidents, multiplied by 100, and divided by the total number of operating platforms each year during a given time period. Table 6 shows nominal accident rates measured as number of accidents per million platform-hours for majors and independents by subcategory of E&P operations for the period 1987-1993.

Despite the fact that independents have a much higher accident rate while drilling, their lower accident rate while producing results in a lower accident rate over all. As can be seen in the bottom row of Table 6, large independents have a lower risk of an accident during oil and gas E&P operations than the majors, while smaller independents as a group have the lowest risk--2.08 per million platform-operating-hours. The nominal accident rate for the period among the majors was 3.34 accidents per million operating platform-hours, while that among the large independents was 3.01 per million operating platform-hours. A principle weakness of this definition is that it gives equal weight to every environmental or safety event regardless of the consequences.

3.1.2 - Weighted Safety Score (WSS): In previous work we differentiated among environmental and safety incidents by the degree of seriousness of the consequences of the incident using a crude 1-5-25 weighting procedure (Pulsipher et al.,1996). Under this scheme a weight of one was assigned if no fatalities or injuries occurred during a recorded environmental and safety event. Accidents with injuries but no fatalities were given a five; accidents resulting in one or more fatalities were assigned

Table 6

Nominal Rate of Accidents During E&P Operations
on the Gulf of Mexico OCS, 1987-1993 (per million platform-hours)

Operation	Majors	Independents			Total OCS
		Small	Large	Total	
Drilling	3.95	11.91	27.81	18.34	5.85
Production	2.70	1.39	1.89	1.65	2.30
Completion/Workover	0.72	3.97	1.46	2.96	1.01
Other	0.38	0.04	0.39	0.23	0.33
Total	3.34	2.08	3.01	2.57	3.06

a weight of 25. The scheme is as subjective as it is simple, but the resulting safety scores do distinguish between trivial and life-ending accidents. Moreover, our results were not very sensitive to the particular weights chosen. An individual operator's safety score is simply the sum of the weighted values for the period.

Table 7 presents weighted accident rates for firms of different sizes by type of offshore operation for the period 1987-1993. Certainly, the risk of an offshore accident among the independents during drilling and work-over operations is still significantly higher than it is among the majors. However, as is evident in the last row of Table 7, the seven-year-weighted safety score for majors during this period was more than twice the estimated safety score for the small independents, and one-and-a-half times that of large independents. Thus, according to this transformation, the majors clearly had the worst safety or accident record while the smaller independents had the best accident record during the 1987-1993 period.

3.1.3 - Relative Safety Index (RSI): Another plausible and useful indicator for comparing the relative safety performance of firms of different sizes during E&P operations is called herein the "relative safety index" (RSI). RSI is defined as the ratio of the share of weighted safety scores to the share of an exposure measure such as the numbers of platforms operated. The conventional expectation is that as a firm's share of the exposure measure rises, *ceteris paribus*, its share in accidents should also rise. To the extent that the RSI for a firm or group of firms rises more or less proportionately, it indicates either more or fewer accidents than the average unit of comparison. In other words, a relative index of 1.00 reflects that during the period, on average, a one-percent rise in the unit's safety score is associated with a one-percent rise in the unit's share of the exposure measure being used. Conversely, an index of less than 1.00 indicates that the unit's safety score has risen less than proportionally when its share of the exposure measure increases.

Table 7

Weighted Rate of Accidents During E&P Operations
on the Gulf of Mexico OCS, 1987-1993 (per million platform-hours)

		Independents			Total
Operation	Majors	Small	Large	Total	OCS
Drilling	12.94	23.82	74.64	44.36	17.09
Production	4.95	2.31	2.69	2.51	4.02
Completion/Workover	3.60	11.91	7.32	10.06	4.45
Other	1.55	0.04	0.55	0.31	1.10
Total	8.00	3.85	5.35	4.65	6.79

Figure 3 shows the average relative safety indices for firms of different sizes from 1987-1993. Independents show a significantly better-than-expected level of environmental and safety performance, with a relative index well below 1.00, whereas the relative safety score index for the majors (seven-year average relative index=1.22) is significantly above the base index of 1.00.

3.1.4 - Injury, Fatality, and Oil Pollution Rates: Relative measures of injuries, fatalities, and spills can also be created with appropriate exposure measures. Table 8 shows such rates with injuries, fatalities and spills expressed per million platform hours. Although these measures do not allow comparisons with other industries, they do permit useful comparisons between majors and independents. Majors have slightly higher injury rates than independents and considerably higher fatality and spill rates.

As noted earlier, however, values for both fatalities and spills are a very small number when compared to their respective exposure bases. For example, the total volume of petroleum reported as spilled during the seven-year period was approximately 34,000 barrels, which is a very small fraction of the 1.8 billion barrels of offshore production recorded for the same period. This is equivalent to approximately 13 barrels spilled per million barrels of oil produced.

Similarly, although we cannot make comparisons to other industries, even workers on offshore drilling and production platforms operated by major oil and gas operators on the OCS face a relatively low risk of injury and fatality--less than one injury per 2 million platform-hours and two fatalities per 10 million platform-hours, respectively. The spill rate for the majors during the period 1987-1993 was 255 barrels per million of platform hours, which translates to approximately 15 barrels per million barrels of crude oil production. Among the independents, the risks of an oil spill are even lower--24 barrels per million platform-hours or 4 barrels spilled per million barrels of crude oil produced.

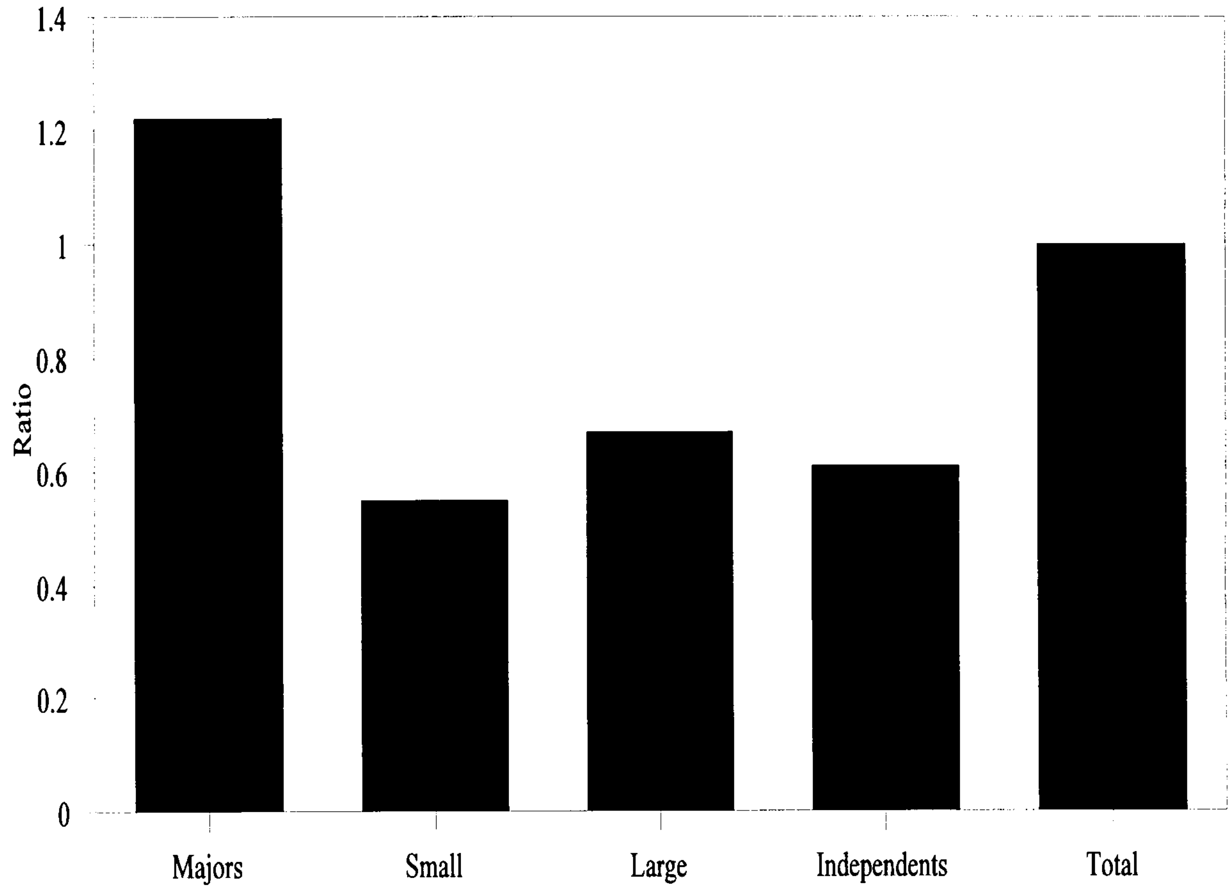

Figure 3. Relative Safety Index, 1987-1993.

Table 8

Injury, Fatality, and Pollution Spill Rates on the Gulf of Mexico OCS, 1987-1993

Effect	Majors	Independents			Total
		Small	Large	Total	OCS
Injuries Per MM Platform-Hours	0.48	0.44	0.43	0.44	0.46
Fatalities Per MM Platform-Hours	0.20	0	0.04	0.02	0.13
Spills (bbl) per MM Platform-Hours	255	20	27	24	172

4. MODELING THE RISK OF ACCIDENTS AND OIL SPILLS ON THE U.S. OCS

The descriptive analysis presented thus far of the types, causes, and consequences of accidents and spills that make their way into the MMS's records provides little evidence to support the fear that the expanded role of independents on the OCS poses a significant threat either to worker safety or to the marine environment. However, many other intervening factors can be hypothesized to affect the safety and environmental performance of firms operating on the OCS: the age of the platforms, the type of product (oil or gas), and the type of activity (drilling or production). Intervening influences of this sort may distort the comparisons we have previously made. In order to quantify and test for such influences and see if they indeed affect the conclusions we have reached thus far, we have specified and estimated models which more fully explore relationships between the characteristics of operators and risks of damage to the environment and to the workers' safety.

4.1 - Specification of the Risk Equation

The empirical framework adopted here assumes that the level of risk, expressed as accident rate and spill rate for firm *(i)* in year *(t)* during oil and gas E&P operations is expected to vary with several factors such as the number, type, and age of operated platforms, MMS's inspection results and safety policies, and firm-specific effects. Symbolically, the general specification of the risk equation to be estimated is of the form:

$$RISK_{it} = \beta_0 + \beta_1 DLRG_t + \beta_2 DSML_t + \beta_3 LINC_{it} + \beta_4 LINC_{it-1} + \beta_5 LAGE_{it} + \beta_6 LWPP_{it} + \epsilon_{it} \quad (1)$$

where $RISK_{it}$ is the dependent variable for a given firm in a given year and ϵ_{it} is an independent random variable.

Two different dependent or outcome variables for risk are used in the subsequent analysis. The first dependent variable is the weighted accident rate we discussed earlier. This measure differentiates the accidents by assigning a weight of one to accidents in which there are no injuries or fatalities, a weight of five to accidents with injuries but no fatalities, and a weight of 25 to accidents resulting in fatalities. An individual operator's safety score is simply the sum of these weighted values for the time period.

The second dependent variable is measured as the total volume (in barrels) of spilled oil per operating platform. In both the weighted accident rate and the oil spill rate specifications, the dependent variable is divided by the number of platforms each operator is responsible for in each year. To estimate the relationship between these two measures and the independent variables, we use the Tobit regression technique, which is designed to measure the association between independent variables and dependent variables when many observations on the dependent variable are zero or less than zero. In our models, these zero values represent the absence of recorded accidents or spills. Natural logs were taken on the independent variables used in the estimation.

The independent or explanatory variables and their hypothesized relationships to the dependent or outcome variables are defined as follows:

> $LAGE_{it}$ -- The logarithm of the average age of the set of platforms for each firm. Our hypothesis is that accidents and spills are more likely to occur on older platforms.

$LWPP_{it}$ — The logarithm of the number of wells drilled per drilling or drilling-and-production platform.[1] The hypothesized relationship is that drilling provides more opportunity for accidents than production. Drilling crews are five or six times larger than production crews, and drilling is usually a more complex and uncertain activity. We expected this variable to have a positive relationship with the dependent variable.

$LINC_{it}$, $LINC_{it}$ — Proxies for the impact of the MMS' safety inspection program on each operator. It is measured as the logarithm of the contemporaneous and lagged (by one year) incidents of noncompliance (INCs) with safety regulations recorded against the operator during the inspection process. Two hypotheses about how INCs are related to accidents and spills can be tested. The first is that as INCs are noted and corrected, the risk of future accidents or spills declines. Thus, the two INC variables should be inversely related to the accident and spill rates; i.e., the coefficients should be negative. The second hypothesis is that INCs are more important as measures of managerial attitudes and performance than as a means of identifying unsafe equipment or practices. The greater the number of INCs, the less safety conscious and effective the platform's management and the more likely accidents and spills. Thus, the coefficient of the INCs variables should be positive.

$DLRG_t$, $DSML_t$ — Dummy variables for, respectively, large independents and smaller independents. To test directly for group differences in the safety records of majors and independents, we classified each operator as either a major oil and gas company (18 firms), a large independent company (35 firms with total assets worldwide in excess of $500 million), or a small independent company (90 firms, including all other operators active on the OCS during the period). Groups were assigned "dummy variables" to measure the association between the classification and the dependent variables. These dummy variables are intended to capture the effects of the factors associated with the firm size. Statistical significance of the parameter estimates for these dummy variables indicates the presence of the size-of-firm-specific effects; conversely, if parameter estimates are not significant, such effects are not present. The coefficients for both large and small independents are measured relative to the majors; thus, a negative coefficient means that being an independent operator is associated with having better safety or environmental records, compared to majors.

DV88, DV89, DV90, DV91, DV92 — Dummy variables for the years 1988 through 1992. The dummy variables for each year are included in the specification to control for any time-specific effects. Such effects might include changes in regulations, especially severe or benign weather, or important changes in economic conditions such as major oil price increases or declines. To prevent singularities, the dummy for 1987 was dropped from the specification. The parameter values for the dummy variables can be used to compare the relative safety performance of firms of different sizes while holding all other variables in the equation constant (Pindyck and Rubinfeld, 1991).

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[1] As explained earlier, our data base includes only operating platforms. Operating platforms are classified as (1) "production," (2) "drilling," or (3) "drilling-and-production." The variable uses only the last two types of platforms.

4.2 - Estimating the Risk Equations

Table 9 presents the pooled regression estimates using the Tobit estimation technique.[2] We employ the Tobit estimator because our data on both oil spills and accidents are left-censored.[3] This censoring occurs because a large number of firms in the data set have no reported accidents or spills. In such a situation, standard OLS is biased.[4] Our Tobit model takes the following form:

$$\begin{aligned} y_i &= \beta' X_i + u_i \quad \text{if} \quad WSS,\ SPILL > 0 \\ y_i &= 0 \quad \text{otherwise} \end{aligned} \qquad \textbf{(2)}$$

where, β is a $k \times 1$ vector of unknown parameters to be estimated and X_i is our $k \times n$ vector of explanatory variables outlined earlier.

The two columns in Table 9 report the parameter estimates for the models with the weighted accidents per operating platform (Equation I) and with the barrels of oil spilled per operating platform (Equation II) as the dependent variables. The parameter estimates for all but one explanatory variable are statistically different from zero and have the hypothesized signs.

4.2.1 - Analysis of the Accident Model: The effects of both the contemporaneous incidents of noncompliance (INCs) per inspection and the lagged value of INCs per inspection on the expected risk of an accident were negative. This is consistent with the first hypothesis that the more INCs recorded (and corrected) per inspection, the lower the number of accidents per operating platform. A one-percent increase in the contemporaneous MMS policy variable reduces the safety scores by 0.2099 percent, whereas an increase of one percent in the lagged value of the policy variable reduces the safety scores by 0.0914 percent.

As hypothesized, the parameter estimate for the variable representing drilling activity--wells drilled per drilling or drilling-and-production platform--is positive. Therefore, we conclude that the intensification of drilling activities, according to our model, does in fact entail a statistically significant increase in accident rates: a one-percent increase in wells drilled per platform leads to a 0.1104 increase in the accident rate.

The regression results support the hypothesis that the average age of operators' platforms is directly associated with accidents. According to our estimates, a one-percent increase in the average age of platforms leads to a 0.3632 percent increase in the rate of accidents. Thus, we conclude that older platforms indeed pose greater risk for accidents.

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[2] Earlier runs indicated the presence of heteroskedasticity. The empirical results presented in Table 3 have been adjusted for this problem.

[3] We used the LIFEREG procedure available in SAS to estimate the Tobit model. By default, LIFEREG procedure models the log of the response variable. Therefore, parameter estimates should be interpreted as elasticities.

[4] Under OLS, a significant number of zero observations has the effect of skewing the regression line, thus biasing the parameter estimates. The Tobit model, first presented by Tobin (1958), adjusts for this shortcoming. See Maddala (1983).

Table 9

Estimated Tobit Risk Equations Using Panel Data
(coefficients and standard errors)

	Equation I	Equation II
Variable	Accident Rate	Oil Spill Rate
Intercept	-1.0605* (0.0424)	-15.6860* (0.0110)
$DLRG_t$	-0.1706* (0.0179)	-11.1572* (0.0012)
$DSML_t$	-0.7100* (0.0306)	-4.9821* (0.0019)
$LINC_{it}$	-0.2099* (0.0133)	-3.9342* (0.0011)
$LINC_{it-1}$	-0.0914* (0.0126)	-3.1379* (0.0010)
$LAGE_{it}$	0.3632* (0.0133)	6.6498* (0.0011)
$LWPP_{it}$	0.1104* (0.0063)	3.6691* (0.0009)
DV88	0.0529* (0.0160)	4.4170* (0.0111)
DV89	-0.0169 (0.0148)	1.6311* (0.0151)
DV90	-0.1903* (0.0156)	30.6224* (0.0102)
DV91	0.6738* (0.0151)	1.4757* (0.0139)
DV92	-0.4114* (0.0193)	4.1350* (0.0112)
# of -2 LOG	831 9951	831 8729522

* significant at the 1 percent level

Since platform age is an important planning and regulatory parameter for MMS and is central to such issues as the development of standards for the assessment and re-qualification of offshore platforms regulations, we also experimented with other measures of platform age. Since the design criteria for offshore platforms were made considerably more demanding in 1977, we calculated the percentage of each operator's platforms installed prior to 1978. Although the variable was significant in three of the four equations we discuss here, statistically it was not quite as stable as the average age measure we used to make the estimates reported here.

Another aspect of the influence of platform age is a fairly common stereotype which visualizes smaller independent operators entering the offshore by purchasing older platforms from majors. However, as depicted in Figure 4, older platforms constitute a considerably smaller proportion of the platforms operated by independents than is true for the majors. There is an increase between 1987 and 1992 for the smaller independents, but the proportion is still well below that of the majors. This trend may have increased since 1992, but we do not have the data necessary to see if that is the case.

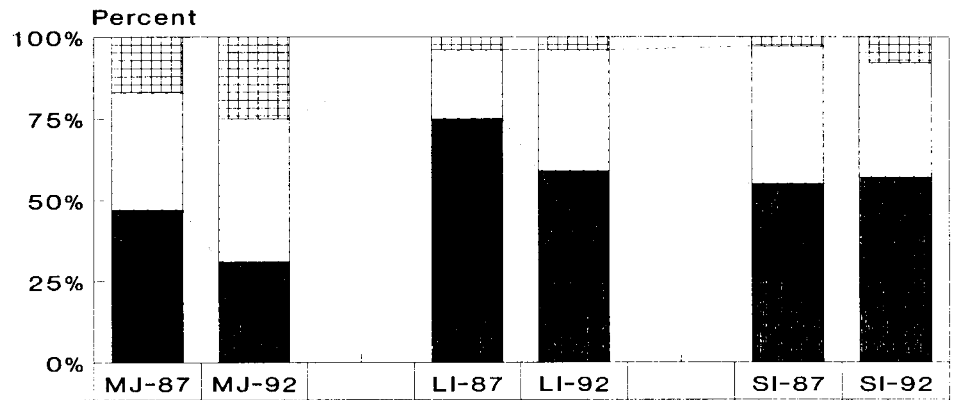
The parameter values for the two firm-specific dummy variables--DLGE and DSML--provide measures by which we may compare the safety performance of independents relative to that of the majors (as measured by the expected number of accidents per platform) during the period 1987-1993.

A logical interpretation of the negative sign of the intercept and the firm-specific dummy variables is that, holding other variables constant, firms operating drilling and production platforms on the OCS are affected by factors we have neither specified nor measured directly that reduce weighted accidents and oil spills. That is, such factors reduce our accident and spill estimates relative to the values we would expect if the dummy variables that capture these effects were not included in the regression equations. The estimated parameters of the firm-specific dummy variables suggest that such factors reduce the weighted accident rate of majors by 35.2 percent, that of large independents by 66.5 percent, and that of small independents by 53.1 percent.

The parameter estimates for the two size-of-firm-specific dummy variables--DLGE and DSML--provide measures by which we may compare the safety performance of independents relative to that of majors during the period 1987 to 1993. These variables reveal that both small and large independent operators tend to have, on average, lower accident rates than majors. These results confirm our earlier findings that independent firms do not pose greater safety or oil spill risks than do the majors.

The year-by-year dummy variables have both positive and negative signs, reflecting fluctuations in other factors which affect the rate of accidents. Relative to 1987, more accidents per platform were associated with 1991. The rest of the years (excluding an insignificant parameter estimate for 1988) were associated with lower accident rates.

4.2.2 - Analysis of the Spills Model: With respect to the model specification, total barrels of oil spilled, as reported by MMS, is analogous to the count of weighted accidents because both indicators vary with the safety of the offshore operations. Thus, we assumed that the factors which were hypothesized to be associated with accidents could be also associated with oil spills. Here, we repeat the Tobit estimation procedure using barrels of oil spilled per operating platform as the dependent variable.



	MJ-87	MJ-92		LI-87	LI-92		SI-87	SI-92
> 26 years	17	25		4	4		3	8
> II < 26	36	44		21	37		42	35
< 11 years	47	31		75	59		55	57

Source: Calculated from MMS data.

Figure 4. Age Distribution of Offshore Platforms, Majors and Independents: 1987 Compared with 1992.

The model for the spill rates (volume of oil spilled per operating platform) performs quite satisfactorily. All of the parameter estimates of the explanatory variables are statistically significant at the 1-percent level. Most of the coefficients in the spill rate model have the same signs as the coefficients in the accident rate model, thereby giving support to our hypothesis about the commonality in the behavior of the two safety measures.

According to our results, the effect of platform age on oil spills is positive: a 1-percent increase in the average age of platforms corresponds to a 6.6-percent increase in the volume of oil spilled per platform. However, the combined effect of the contemporaneous and lagged values of INCs per inspection is large enough to negate the impact of the aging process. A one percent increase in the two INCs variables reduces oil spills rate by about 7 percent, *ceteris paribus*.

Size-of-firm-specific unmeasured factors that tend to reduce oil spills are evidenced by the negative signs of the type of the dummy variables. Our results suggest that these factors appear to have a greater effect on independents than on majors, as is indicated by the magnitude of the parameter values for the dummy variables for the two groups. Thus the regression modeling results are consistent with, and support, the comparisons made earlier.

4.3 - Outlier Analysis

The final aspect of accidents and spills that we have attempted to analyze is the so-called "bad actor" hypothesis. are even lower--24 barrels per million platform-hours or 4 barrels spilled per million barrels of crude oil produced. According to this "theory," some firms operating on the OCS are so much more willing to bear risks of accidents or spills than the average firm that they unduly influence the overall record of the offshore industry. In our previous analysis of the economic performance of majors and independents, we tested for "outliers" and found that few firms in either the major or independent categories fit the criteria (Iledare et al., 1995; Pulsipher et al., 1996). Our method was relatively simple. We used our regression equation to predict the dependent economic variables (measures of petroleum reserve additions) for each firm and then compared actual and predicted variables. Where the difference or residual from these comparisons was so large that the probability was very low that it was the result of random variation, we designated the firm as an outlier.

However, the economic data we used in this earlier research was continuous and did not have the "lumpy" character of the accident and spill data. The "lumpiness" of the accident and spill data results from the fact that a relatively large number of the firms in our data base did not report any accidents or spills for some or all of the years in our study period. It was precisely for this reason that we chose the Tobit technique for our empirical analysis.

Although the Tobit technique is better than the more common regression techniques in analyzing the relationship between independent or intervening variables and our safety and oil spill measures when the data are lumpy, the technique is not suitable for conducting the type of outlier analysis mentioned above. Because of this, we have used the more traditional "weighted least squares" regression technique in which all annual values for variables are combined over the study period. Our objective is simply to formulate equations which give useful predictions of accidents and oil spills, not to determine or test the associations between dependent and independent variables.

4.3.1 - Data: The data we have used come from the same data base as our previous analysis but are combined over the entire 1987 to 1993 period; therefore, we have no time-specific, i.e., annual, variables as in the previous analysis. The two measures we have used are the weighted accident rate and quantity of oil reported as spilled. Accidents or spills occurring on a platform either prior to its acquisition or after its sale accrue to the responsible operator at that time, not to the current operator. An individual operator's safety score is simply the sum of these weighted values for the period. Similarly, an individual operator's spill score is the sum of the barrels the operator has reported as spilled during the study period.

The individual operator's cumulative safety score and cumulative oil spill score would be expected to vary with a number of factors such as the number, type, and age of the platforms operated. In order to account for, or "hold constant," such factors, we have used least squares multiple regression analysis. This allows us to (1) estimate the association between accidents and several hypothesized explanatory variables as well as (2) predict a safety score for an individual operator or group of operators which reflects its unique circumstances and then (3) compare such predicted values to the measured value to statistically identify "better" or "worse" (than expected) safety records.

4.3.2 - Predictive Variables: The variables included in the regression equations are the dependent variable (I), which is the cumulative weighted accident score or the cumulative number of barrels spilled for each operator, and the following independent or explanatory variables:

> LPLTY - Platform years as the summation of the number years of platforms operated in each year by the operator over the study period. The hypothesis is that more platform years provide more opportunity for accidents.

LAVAGE - Average age of the operator's platforms. The hypothesis is that older platforms are less safe.

LWELLS - Number of wells drilled. The hypothesized relationship is that drilling provides more opportunity for accidents than production.

LGPLT - Percent of platforms producing gas. The hypothesis is that gas production is more accident prone than oil production.

LINCS - Cumulative number of INCs (incidents of noncompliance recorded against the operator during the MMS inspection process). As explained previously, hypotheses consistent with either a positive or a negative coefficient are plausible.

To test directly for differences among the safety records of majors and independents considered as groups, we also classified each operator as either a major, a large independent, or a smaller independent as defined in Section 4.1 of this report. Groups were assigned "dummy variables" to measure the association between group membership and safety scores. Large independents were designated in the regression equations as LARGEI and smaller independents as SMALLI.[5] Symbolically, the form of the equation estimated was:

Logarithmic transformations of all of the continuous variables, including the dependent variable, are taken in the estimation procedure. These transformations help minimize potential heteroskedasticity problems as well as yield parameter estimates which can be interpreted as elasticities. No dummy variable for majors is included in the equations. It was necessary to exclude the classification variable for major operators in order to give the regression a reference point and to prevent a possible econometric specification error. The parameter values for LARGEI and SMALLI are interpreted as values relative to the excluded base: in this instance, relative to major operators. Thus, if the parameter value of LARGEI is negative, it means that large independents tend to have fewer accidents relative to major operators.

4.3.3 - Regression Results: Data analysis indicated the presence of heteroskedasticity in the residuals. Specifically, the errors tended to grow with increases in the number of operator platform years. Thus, weighted least squares (WLS) was applied to both sets of regressions with the variance of platform years (LPLTY) being used as weights in order to correct for this problem and yield more reliable estimates.

The empirical results for both the accident and spill equations (1) are presented in Table 10. The summary statistics (R^2 and adjusted R^2) for the accident equation are both relatively high, explaining some 70 to 72 percent of the variation in operator safety scores. We found five of the seven explanatory variables to be statistically significant at the 95-percent level. These variables included operator classification (LARGEI, SMALLI), platform years (LPLTY), number of wells (LWELLS), and average age of platform (LAVAGE). In addition to the statistical significance, we found that all of the signs resulting from the parameter estimates were of the anticipated direction (except the percentage of wells producing gas, which was not statistically significant).

Both regressions indicate large and small independents considered as groups have better safety records than majors.

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[5] The hypothesized relationship is positive according to the conventional wisdom but is a central research question for us.

Table 10

WLS Regression Results
(standard errors in parentheses)

	Equation 1	Equation 2
Variable	Accidents	Spills
Intercept	0.5154	2.2922
	(0.4902)	(1.0096)
LARGEI	-1.4473	-2.6916
	(0.2411)	(0.4965)
SMALLI	-1.3628	-3.1038
	(0.2687)	(0.5534)
LPLTY	0.2049	0.1381
	(0.0960)	(0.1977)
LGPLT	-0.0842	-0.1716
	(0.0617)	(0.1270)
LWELLS	0.2467	0.5437
	(0.0805)	(0.1658)
LAVAGE	0.2191	0.4283
	(0.1098)	(0.2262)
LINCS	0.0385	-0.0383
	(0.0752)	(0.1548)
R^2	0.7233	0.6429
Adjusted R^2	0.7079	0.6231
# of Observations	136	136

Cumulative barrels of oil spilled, as reported to MMS, is computationally analogous to our safety score measure. Since circumstances we hypothesized as being associated with our safety score should also be associated with oil spilled, we repeated the procedure summarized in the preceding section using barrels of oil spilled as the dependent variable. Although the oil spill equation explained only about 60 percent of the variation among operators in oil spilled--as opposed to 70 percent in the weighted accident equation--the significance levels and relative magnitudes of the explanatory variables retain the same pattern and support the same inferences.[6]

Because of the higher R^2, we used the accident data to conduct our outlier analysis. It is useful to keep the intent of outlier analysis in mind. We are only interested in using this regression equation to predict performance for individual operators. Thus we have formulated the equation in a way we "expect" to give us the best estimate--but not necessarily the most precise or discerning measurement of the relationship between dependent and independent variables.

Measuring our dependent variable as a cumulative total--rather than as accidents or spills per platform, as we did previously in the Tobit equation--and including as independent variables cumulative platform years may seem like using measurements of individual's circumference at the waist multiplied by the individual's height to predict weight. The method almost tautologically "guarantees" the hypothesized result and may obscure subtler but important influences such as age or diet. However, purely as an estimation technique it may be a very effective and simple way to predict weight. Analogously, we expect cumulative platform years to be the best predictor of cumulative accidents and cumulative spills. In effect, in this section, our objective is to identify those firms where this close, semi-tautological and expected relationship does not work.

4.3.4 - Empirical Analysis: We conducted an analysis of the residuals from our model to identify operators whose safety score differed significantly from our predictions. These residual "outliers" were identified via the use of studentized (or standardized) residuals as outlined in Belsley et al. (1980). These studentized residuals are closely related to the t-distribution. Thus, studentized residuals of absolute value greater than 2.61 are said to be significant at the 99-percent confidence level. Studentized residuals with absolute values greater than 1.98, 1.65, and 1.28 are said to be statistically significant at the 95-, 90-, and 80-percent levels, respectively. Positive values indicate that the actual safety scores are higher than predicted (holding operator classification, gas percentage, wells drilled, platform years, age, and INCs constant). The reverse is true for negative values.

Certainly there are some "other factors" which contribute to accidents--which we attempted to measure in the firm-specific and time-specific variables in the Tobit model--that are unaccounted for in these formulations. Such factors could include economic conditions influencing the operator or industry as a whole, management safety attitudes, managerial efficiency regarding accident prevention, employee safety education, etc. Most of these variables are difficult to quantify. Given our budget and time constraints, we leave them to future research.

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[6] The exceptions were the variables measuring the percentage of gas wells and, in the spills equation, platform years. In the safety score case, we anticipated a positive association between the safety score and the proportion of gas wells (because of a higher potential for explosions and compressor accidents) and in the oil spill case a negative association (because gas escapes as a vapor not as a liquid). We found negative associations in both cases, but in neither case was the association statistically significant. Platform years had the hypothesized sign in both equations but was not significant in the spills equation.

Figures 5 and 6 are graphical presentations of the studentized residuals from our weighted accident regression. Figure 5 presents positive studentized residuals by operator. These preliminary results can be interpreted as a mapping of those operators whose safety scores were greater than those predicted by our model; i.e., they were worse than expected given the number, age, etc. of the operator's platforms. Thus, it may be somewhat misleading to visualize the situation depicted in Figure 2.1 on an operator-by-operator scale. That is, if the number of platforms operated by the "worse-than-expected" operators were used, rather than the number of operators, per se, about 26 percent of the total number of platforms (as contrasted with 5.8 percent of the operators) would fall into this category

The reason for the difference is the large number of platforms operated by the three majors included in the category.

To see if the outliers exerted "undue influence" on our parameter estimates, we "re-ran" the weighted least squares formulations without outliers. We found that, as one would expect, with outliers (defined as residuals beyond the 10-percent confidence level) excluded from the analysis, the fit of the model to the data was significantly improved. The adjusted R^2 for the equation using the weighted accident index as the dependent variable increased by about ten points--from 70 to 80 percent. The R^2 for the equation using the quantity of oil reported spilled increased by about 20 percentage points from about 60 to over 80 percent. In both cases, however, the pattern and relative strength of the explanatory variables remained the same. In the spill equation, the variable measuring the percentage of platforms classified as primarily producing gas became significant at the 10-percent level, but the significance and signs of all other variables remained the same.

Our interpretation of the relationship of this result to our initial research questions is that it contradicts what we termed the "bad actor hypothesis." That is, neither the accident nor the spill equations appear to be skewed, distorted, or dominated by poor records of individual operators. Excluding operators with poor records from our analysis did not change either the pattern or the significance of factors we have used to try to explain the pattern of accidents or spills on the OCS.

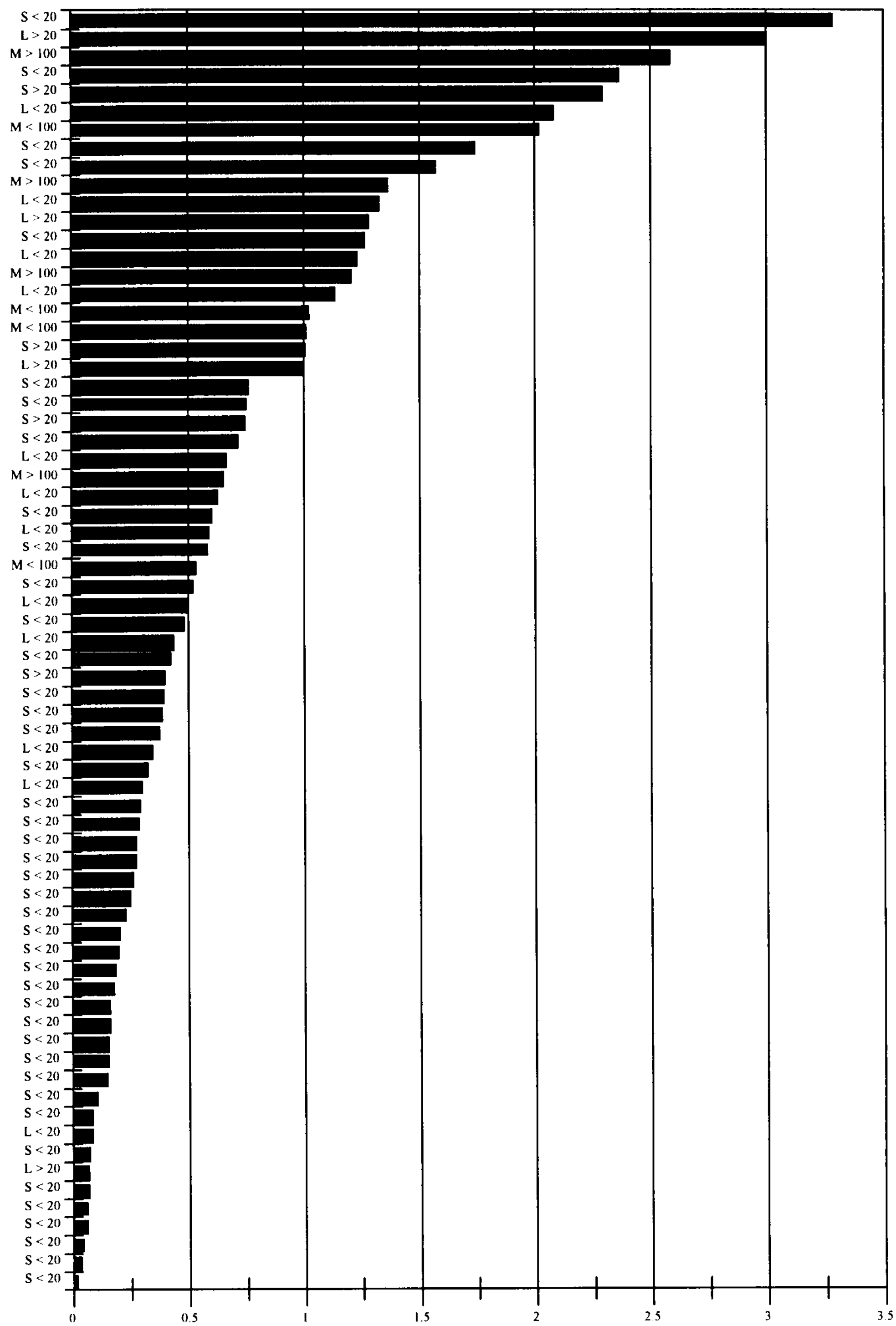

Figure 5. Positive Studentized Residuals by Operators.

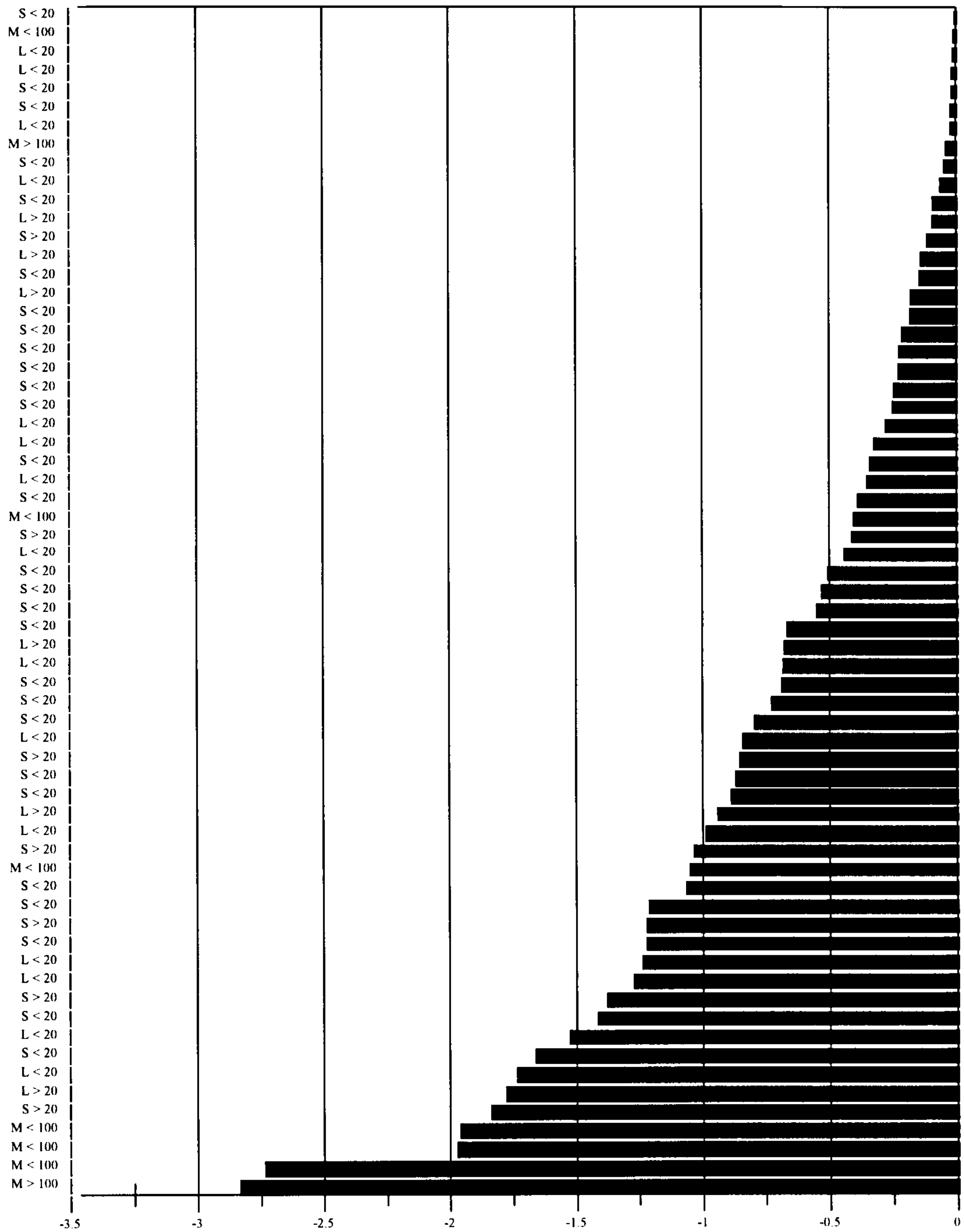

Figure 6. Negative Studentized Residuals by Operator.

5. SUMMARY AND CONCLUSIONS

In this report we have attempted to ascertain if there is persuasive empirical evidence to support the widespread concern that an expected increase in the independents' relative share of exploration and production (E&P) operations in the Gulf OCS region will be detrimental to worker safety or the marine environment. Our method has been to identify and analyze factors underlying the frequencies of accidents or spills in oil and gas E&P operations in the Gulf and to see if they are associated systematically with firm size.

5.1 - Comparisons of Independents and Majors Using Descriptive Statistics

For a comparative analysis of the relative safety performance of firms of different sizes, we distinguished between two broad measures--nominal and weighted accident rates. The average accident rate among majors for the 1987-1993 period was 3.34 accidents per million hours of platform operation. Large independents averaged 3.01 accidents per million platform hours, while smaller independents as a group had the lowest rate--2.08 accidents per million platform hours.

When accidents were weighted by severity using the 1-5-25 values for no injury, injury and fatality respectively, majors had the highest average accident rate of 8.00 per million platform hours, while large independents averaged 5.35 and smaller independents averaged only 3.85. According to these measures, the majors pose the worst risk of accidents on the OCS, and the smaller independents have the least.

We also calculated a relative accident index by taking the ratio of the share of weighted accidents to the share of operating platforms. Independents show a significantly better than expected ratio, with a 7-year average of about 0.6, whereas the majors' ratio was worse than average at 1.22.

The total volume of petroleum reported as spilled (34,000 barrels) over the period 1987-1993 is extremely low compared to the total crude oil production of approximately 1.8 billion barrels over the same period. The majors, on average, reported about 3.87 barrels spilled per million barrels of oil produced. Large independents spilled 0.45 barrels per million barrels produced, while smaller independents spilled 0.73 barrels per million produced.

These simple comparisons indicate that independents have performed better than majors, and if this performance were to be maintained, independents should not pose additional risks to workers of the environment, should they do relatively more of the E&P in the Gulf.

Since these comparisons may be distorted or skewed by other factors or forces not reflected in these simple measures, we also used regression analysis to provide a more comprehensive analysis of the determinants of accidents and oil spills on the OCS.

5.2 - Regression Analysis

Using a panel data set for the years 1987-1993, we estimated a Tobit regression model of the risk of both accidents and oil spills to analyze the determinants of accidents or oil spills during E&P operations on the OCS. The Tobit model is an appropriate analytical technique because many firms operating on the OCS reported many years of operation without accidents or oil spills during the period of our analysis. In these circumstance, the Tobit modeling technique yields more consistent, unbiased, and efficient estimates of the model parameters than are obtainable using an ordinary least squares approach.

The statistical evidence we have analyzed shows that independents have a marginally better safety record than majors during the period we analyzed--when intervening variables such as the number of platform years, the number of wells drilled, and the age of platforms operated were statistically held constant. The independents' superiority is modest but consistent and statistically significant. This result is contrary to much conventional thinking in both industry and regulatory circles.

5.2.1 - Tobit Estimates: Our Tobit estimates indicate the following:

- The average age of an operator's platforms significantly affects the risk of an accident or a oil spill during E&P operations. According to our Tobit estimates, our weighted accident index would increase by nearly 4 percent if the operator's platforms were to age by 10 percent.

- The two variables measuring the effects of MMS's platform inspection program were also statistically significant. The effect of a 10-percent change in lagged incidents of noncompliance (INCs) per inspection decreases the risk of an accident as measured by our weighted accident rate by about 1 percent, while a 10-percent change in contemporaneous INCs per inspection reduces the weighted accident index by 2.1 percent

- We also conclude that the intensification of drilling activities, according to our model, does in fact entail a statistically significant increase in accident rates: a ten percent increase in wells drilled per platform leads to a approximately 1.1 percent increase in the accident rate.

- The "unmeasured," time-specific variables have statistically significant effects on the risks of an accident or oil spill. The year-by-year dummy variables have both positive and negative signs, reflecting fluctuations in other factors which affect the rate of accidents. Relative to 1987, more accidents per platform were associated with 1991. The rest of the years (excluding insignificant parameter estimate for 1988) were associated with lower accident rates.

- The parameter estimates of the unobservable or unmeasured firm-specific variables also were statistically significant--an indication that majors and large and small independents have characteristics, which influence accidents and oil spills, that we have captured, but not identified, in our regression model. Holding all other factors constant, the large and small independents have characteristics that make them less likely than the majors to have an accident or oil spill during E&P operations.

5.2.2 - Outlier Analysis: We also used regression modeling to test a hypothesis that has considerable support in the oil and gas industry. This is the "bad actor" thesis. It posits that a few operators with poor safety and environmental records dominate the data. We found that on an operator-by-operator basis, the number of outliers that we could define with accepted statistical techniques was rather small--only eight, with a confidence level of 90 percent.

However, among those eight operators were two large majors. Thus, on a platform rather than operator basis, almost 25 percent of the platforms were operated by outliers that our statistical criteria would dub bad actors. We tried to ascertain if the outliers had an "undue influence" on our regression analysis by excluding all outliers from the data base and re-running the regression. Although, as one would expect, the models "fit" the "outlier-less" data better, the pattern or significance of the factors we had hypothesized as independent or intervening variables was not changed.

5.3 - Summary

In summary, to return to our initial research questions, we found no reasons in the historical data available to us to indicate that either worker safety or the marine environment is likely to be more threatened in the future by a mix of operators containing more independents than has been the case in the past.

Every descriptive and regression derived analysis we performed consistently indicated that during our 1987-1993 study period, independents of all sizes had a marginally, but statistically significant, better record than majors measured with either accidents or oil spills.

Our methodology is not adequate to determine if level of risk of accidents or of spills is "correct" from either an economic or a political point of view. But the analysis does seem to us to refute the argument that regulations should be made more stringent because more of the offshore industry's work is likely to fall to smaller independents than has been the case in the past.

Finally, it should be noted that the data available show a remarkable decline in accidents and oil spills over the past two decades. Although, as we have indicated, these data contain too many discontinuities, ambiguities, and uncertainties for us to be confident in using them in our analysis, there is a wealth of qualitative and anecdotal evidence suggesting a very significant improvement. The period we have analyzed lies at the culmination of this improvement. Thus, in historical perspective our measures may be more accurately envisioned as ascertaining the shades of significantly better, industry-wide performance rather than statistically separating the good from the bad or the safe from the dangerous.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.