AB

MEASURING AND COMPARING SAFETY AND ENVIRONMENTAL RECORDS OF OFFSHORE OIL AND GAS OPERATORS

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COMPARING THE SAFETY AND ENVIRONMENTAL PERFORMANCE OF OFFSHORE OIL AND GAS OPERATORS

ABSTRACT

Accidents on offshore oil and gas platforms have declined dramatically during the past decade, yet concern about environmental damages from offshore oil and gas operations seems to have intensified. Some of this concern is premised on a perceived offshore restructuring in which major oil and gas companies have invested more heavily in exploration and production (E&P) in foreign countries leaving more domestic E&P to smaller "independents," assumed to be less careful and capable than majors. We define and compute a simple measure called a "safety score" for each operator, which we argue is a better measure of environmental risk than oil spilled or released. By measuring and accounting for variation in the number, type, activity and age of platforms operated, as well as whether each platform was operated by a major or independent, we are able to account for about 70 percent of the variation in safety scores among operators. But, contrary to expectations, independents have marginally, but statistically significant, better safety scores than majors. We also compare the safety scores of individual operators and develop criteria for identifying "better" or "worse-than-expected" performance by using studentized residuals. [keywords: offshore accidents, safety records, environmental risk of offshore platforms]

1. BACKGROUND

Accidents on offshore oil and gas platforms have declined by an order of magnitude during the past decade, yet concerns about environmental damages from offshore oil and gas operations-- as reflected in a variety of state and federal moratoria on offshore leasing, in legislation such as the Oil Pollution Control Act of 1990, and in studies by the National Research Council [5] and General Accounting Office [3]--seems to have intensified.

A "theory" or premise underlying these concerns that is popular in both industry and regulatory circles is that as major oil companies have shifted their E&P investments abroad more domestic E&P will fall to smaller independent companies, at least in a relative sense; who have neither the majors' technical, scientific or regulatory experience nor their financial resources. Thus in the future:

(1) U.S. petroleum reserves would be less aggressively and efficiently developed, and

(2) safety and environmental risks inherent in the development of those reserves would also grow.

We have found little empirical evidence to support these concerns in the historical data available for the federal OCS.

Our analysis of the economic component of the argument suggests that the investment strategies of independents have mirrored the majors' shift toward foreign prospects, with the rate of substitution of domestic for foreign E&P investment about the same for majors and large independents and that independents were both more aggressive and more successful than the majors in developing domestic oil and gas reserves [4],[9]. In this article we deal only with safety and environmental concerns and our empirical results indicate that independents have, at least marginally, a better safety record than the majors.

A serious obstacle to the analysis of offshore safety has been the data. To date, no comprehensive, consistent and accessible data base records operator-specific safety performance. This shortcoming was underscored recently in a report prepared by the Marine Board's Committee on Alternatives for Inspection of Outer Continental Shelf Operations [5]. The Committee recommended that:

> MMS improve its collection, analysis, and use of safety-related data regarding offshore operations. This recommendation is based on the fact that improvements in safety performance derive in large part from past lessons. To learn from past experience demands a clear perception of what that experience has been. This means that the data base on OCS operations must be made more comprehensive and accessible. It must include more information, which must be organized and processed so that proper inferences can be made, conclusions clearly drawn, and lessons readily learned.

The substantial part of the work embodied in this research entailed beginning to create such a data set from which "lessons could be learned." While far from perfect, the compilation of data used here allows testable empirical inferences to be drawn from past operator performance, and the operator-specific characteristics conditioning that performance, in the federal Gulf of Mexico OCS.

We have not measured or compared the environmental records (i.e., environmental damages resulting from accidents on offshore platforms) because damage data are neither defined nor available. MMS collects data on quantities of oil reported spilled by each operator and our analysis of this data shows the same pattern--a marginally but statistically significant better performance by independents.

However, we believe that our safety index is a better measure of environmental risk than oil spilled as reported to MMS. Geographic isolation of many offshore platforms makes self-reporting a questionable strategy and inspections difficult and expensive. Further, vast improvements in spill prevention technology have made major oil spills rare and spasmodic events.[1] More importantly, the environmental risk that is of primary concern to the public is the ecological catastrophe not the relatively minor spills that dominate the MMS data.

The potential for catastrophic (albeit extremely low probability) environmental damage exists anytime an offshore accident occurs. The Ixtoc I blowout in Mexico's Gulf of Campeche spewed oil for ten months at a rate of 310,000 barrels per month--dwarfing the largest and most infamous U.S. blowout in the Santa Barbara channel which released 77,000 barrels over a one month period in 1969.

Safety data, especially when injuries or fatalities are involved, is much less likely to be under- or unreported and serious accidents involving injuries or fatalities are more likely to be associated with potentially catastrophic environmental consequences. Thus in our view it may be more accurate to base inferences about the potential environmental risk from the operator's safety record--the poorer the safety record the greater the potential environmental risk.[2]

2. METHODS

2.1 Data: For this paper we assembled a consistent data base from published and unpublished MMS data for each OCS operator and cross checked it with data from Offshore Data Services. The data are organized on a platform as well as an operator or a production basis and cover the 1980 to 1994 period.

2.1.1 Accidents and Safety Scores: Since accidents vary greatly in their seriousness or consequences, we differentiated among them with the following crude weighting scheme. Accidents in which no injuries or fatalities were reported were assigned a weight of one, accidents with injuries but no fatalities were weighted as five, and accidents resulting in fatalities were counted as twenty-five. Admittedly this (1-5-25) scheme is as subjective as it is simple, but experimentation with other schemes suggests to us that the results are not very sensitive to the particular weights chosen. Accidents occurring on a platform either prior to its acquisition or after any sale accrue to the responsible operator at that time, not the current operator in that year. An individual operator's safety score is simply the sum of these weighted values for the period.

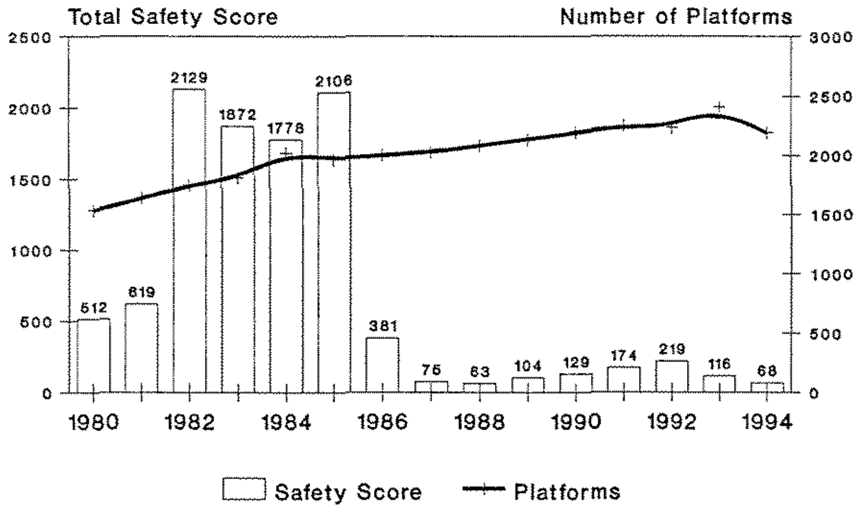
There has been rather extreme variation in the cumulative safety score for all operators over the study period as illustrated in Figure 1. At the crest of the domestic oil boom in the early 1980s when in expectation of $50/barrel-oil-forever, 200 or more new platforms were being installed annually on the OCS (with inexperienced workers on rush schedules) accidents soared. The cumulative safety score as we have defined it jumped from about 500 in 1980 to around 2000 between 1982 to 1985. When the world oil price dropped, so did OCS activity and so did OCS accidents--with the industry's annual safety score falling from 2,100 in 1985 to less than 400 in 1986. Less dramatic but perhaps more significant is the fact that the offshore industry's safety score remained at very low levels after OCS activity revived in the later 1980s and 1990s. As can be seen in Figure 1 there is about an order of magnitude difference between accident-scarred early 1980s and the post-price-collapse period--despite, as measured on the left axis, a steadily growing number of operating platforms.

2.1.2 Explanatory Variables: The individual operator's safety 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 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 their own unique circumstances; and then 3) compare such predicted values to the measured value to statistically identify "better" or "worse" (than expected) safety records.

The variables we have included in the regression equation are the dependent variable (I) which is the safety score for each operator and the following independent or explanatory variables:

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

Figure 1 - Total Safety Score Compared with Total Number of Operating Drilling and Production Platforms, 1980 to 1994



Note: Total safety score per text, non-drilling or production platforms and platforms w/o data are excluded.

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

- LWELLS - Number of wells drilled--the hypothesized relationship being 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 (instances of noncompliance recorded against the operator during the MMS inspection process)--the hypothesis being the larger the number of INCs the more likely accidents are to occur.

To test directly for differences among the safety records of majors and independents considered as groups, we also classified each operator either as a major (18 firms as usually identified), large independent (35 firms with total assets world-wide in excess of $500 million) or smaller independent (90 firms including all other operators active on the OCS during the study period). 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.[3]

2.2 Procedure: Because of the extreme variation in the safety scores and associated independent variables observed in the pre- and post-price-collapse periods, and because of limited MMS inspection data prior to 1987, two periods were used to estimate the regression equations, 1980-1986 and 1987-1994.

Symbolically, the form of the equations estimated for the two periods was:

$$[Eq.\ 1] \quad (\,I_i\,|_{1980\text{-}1986}\,) = \beta_0 + \beta_1 LARGEI_i + \beta_2 SMALLI_i + \beta_3 LPLTY_i + \beta_4 LGPLT_i + \beta_5 LWELLS_i + \beta_6 LAVAGE_i + \eta_i$$

$$[Eq.\ 2] \quad (\,I_i\,|_{1987\text{-}1994}\,) = \beta_0 + \beta_1 LARGEI_i + \beta_2 SMALLI_i + \beta_3 LPLTY_i + \beta_4 LGPLT_i + \beta_5 LWELLS_i + \beta_6 LAVAGE_i + \beta_7 LINCS_i + \epsilon_i$$

As indicated by the notation above, Eq. 1 covers the period from 1980 to 1986 while Eq. 2 covers the period from 1987 to 1994. Logarithmic transformations of all of the continuous variables, including the dependent variable, have been taken in each of the models. These transformations help minimize potential heteroskedasticity problems as well as yield parameter estimates which can be interpreted as elasticities. Other than the time periods analyzed, the two equations differ in one other respect: incidents of non-compliance (LINCS) have only been included in Eq. 2 since the inspection data are not readily available for the earlier period.

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.

3. RESULTS

Analysis of the data 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.

3.1 Majors' and Independents' Safety Performance: The empirical results for [Eq. 1], which span the period 1980-1986, are presented in the first two columns of Table 1. The summary statistics for the model are good. The R^2 and adjusted $\bar{R}^2$ are both reasonably high and indicate that the hypothesized model captures some 70 to 71 percent of the variation in the safety scores.

Three of the six variables were significantly different from zero at the 99 percent level as evidenced by t-ratios which exceed an absolute value of 2. The three variables which proved to be statistically significant included: the indicator for large independent operators (LARGEI); the indicator variable for small independent operators (SMALLI), and the number of platform years (LPLTY). 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 significant statistically).

The regression indicates that during the period 1980 to 1986, both large and small independents tended to have better safety records than the majors. Some algebraic manipulation of the results[4] also tells us that, holding other things constant, a shift of operator classification from a major to a small independent would result in 0.96 percent reduction in the operator's expected safety score. A shift from the major classification to large independent would result in a 0.90 percent reduction.

The analogous empirical determinants of accidents during the 1987-1994 time period are shown in the last two columns of Table 1. The summary statistics (R^2 and adjusted R^2) are both relatively high explaining some 70 to 72 percent of the variation in operator safety scores. The parameter estimates presented in Model 2 are generally consistent with the results found in the 1980-1986 model. In this model, however, 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). The estimates for the two classifications of independents are similar to those of the 1980-1986 period, as is the estimate of the platform-years variable.

Table 1: Empirical Results -- Index of Operator Accidents

Variable	1980-86 Parameter Estimate (Std Errors)	1980-86 T-Ratios	1987-1994 Parameter Estimates (Std. Errors)	1987-1994 T-Ratios
INTERCEPT	1.804269 (0.89109841)	2.025	0.515357 (0.49028377)	1.051
LARGEI	-2.312938 (0.46252361)	-5.001	-1.447334 (0.24113063)	-6.002
SMALLI	-3.288777 (0.53819132)	-6.111	-1.362809 (0.26875779)	-5.071
LPLTY	0.482109 (0.17346319)	2.779	0.204935 (0.09598936)	2.135
LGPLT	-0.084118 (0.11660727)	-0.721	-0.084200 (0.06165584)	-1.366
LWELLS	0.161634 (0.12554486)	1.287	0.246714 (0.08053146)	3.064
LAVAGE	0.145651 (0.22146305)	0.658	0.219109 (0.10983526)	1.995
LINCS	NA	NA	0.038510 (0.07515702)	0.512
R^2	0.7144		0.7233	
Adjusted R^2	0.6981		0.7079	
n =	115		136	

3.2 Oil Spilled by Majors and Independents: 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 model explained only about 60 percent of the variation among operators in oil spilled--as opposed to 70 percent in the previous safety score model--the significance levels and relative magnitudes of the explanatory variables retain the same pattern and support the same inferences.[5] All of the variables that were significantly related to safety scores were significantly related to oil spilled and the signs of the coefficients were the same. As argued previously, however, we believe the safety score is a better measure of the nature of the environmental risk of primary public concern than is the annual amount of oil spilled, thus we have used safety scores to conduct the "outlier" analysis described in the following section.

3.3 Outlier Analysis: We also 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, [2]. 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 level, respectively.

While absolute values are important in determining statistical significance, it is the sign of the residuals (positive or negative) which gives us some inference regarding whether deviations between actual and predicted represent better (or worse) than expected safety scores. 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 would be true for negative values. Certainly there are some "other factors" which contribute to accidents which are unaccounted for in our model. 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. Although many of these variables are difficult to quantify, future research will try to identify more of the sources of the unexplained deviation.

Figures 2.1 and 2.2 are graphical presentations of the studentized residuals from our 1987-1994 regression model. A similar analysis was done for the 1980-1986 model.

Figure 2.1 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 in our model. Figure 2.2 presents the negative studentized residuals by operator. These preliminary results can be interpreted as a mapping of those operators whose safety scores were better than what was predicted in our model.

Probably the most significant result is the relatively small number of outliers. Using a 90 percent significance level, in the 1987-1994 period there were eight (5.8 percent of total) in the "significantly-better-than-expected" group and seven (5.1 percent of total) in the "significantly-worse-than-expected" group. This leaves 89 percent in the "not-significantly-different-than-expected" category.

However, the composition of both groups is equally important. Although we are not willing to identify individual operators at this stage of our research, we have indicated their relative size by noting intervals for the maximum number of platforms operated during the period.

Figure 2.1 Studentized Residuals for Operators With Worse-Than-Expected Safety Scores

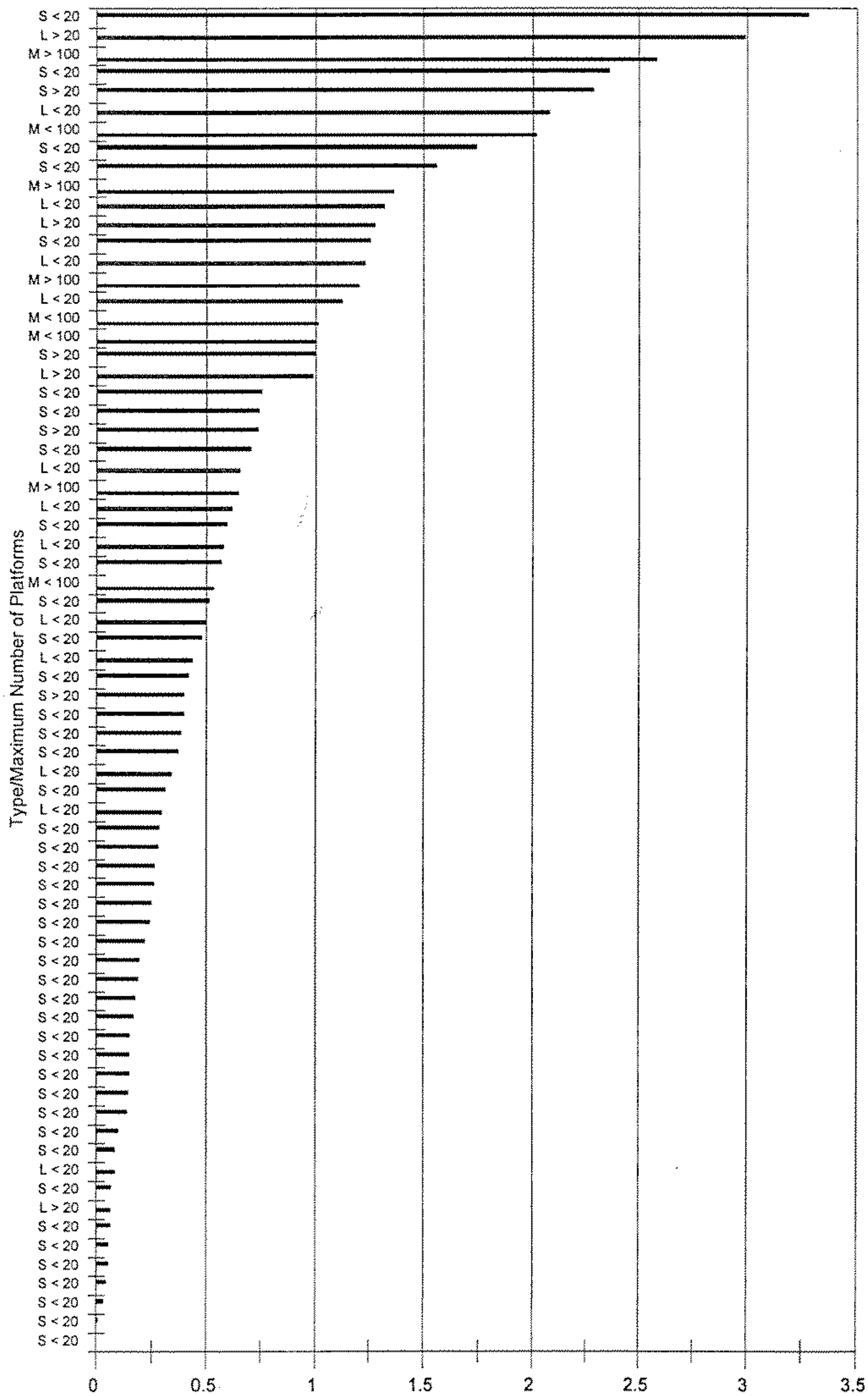
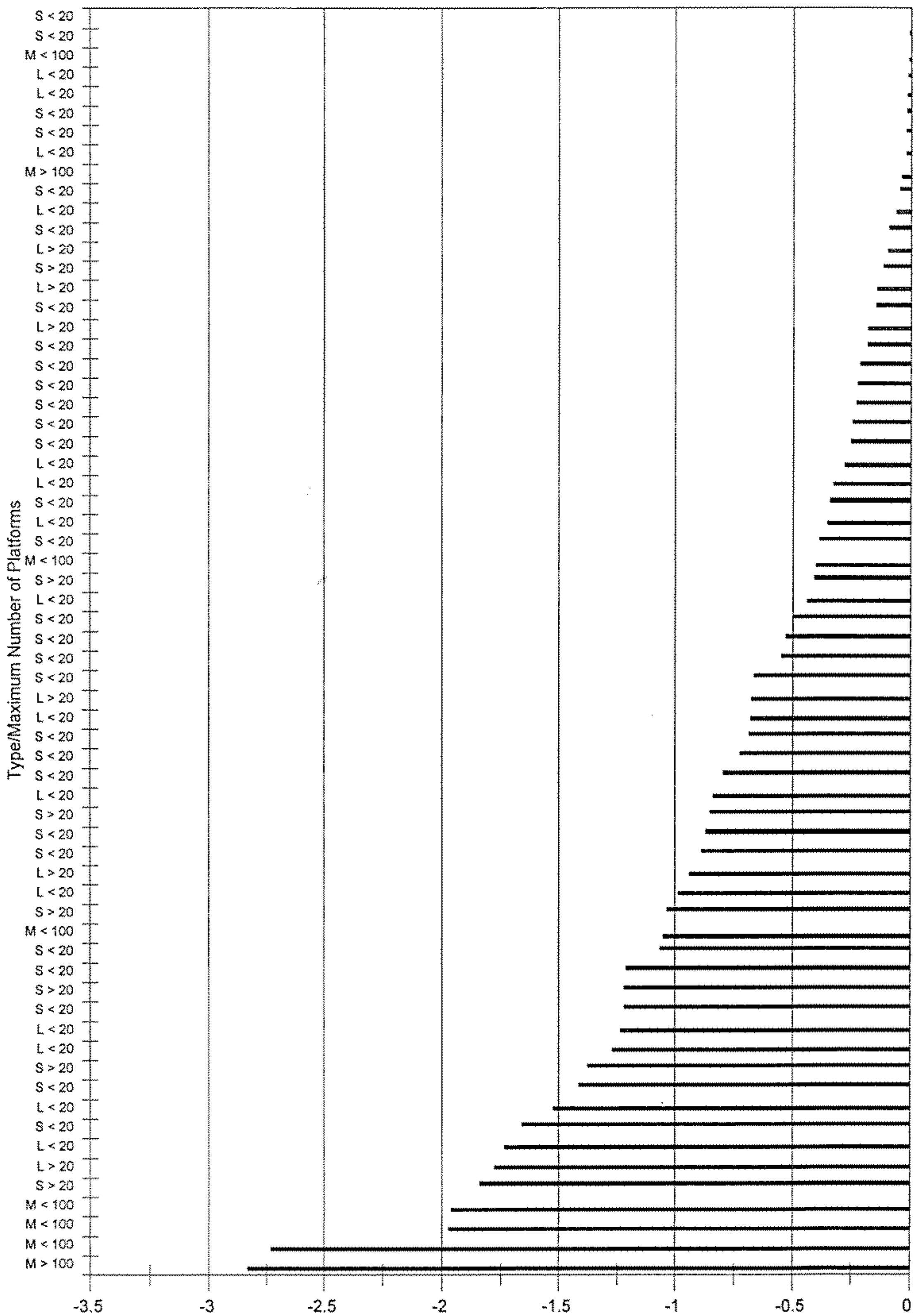


Figure 2.2 Studentized Residual for Operators With Better-Than-Expected Safety Scores



We have divided majors and independents into two groups. Majors are categorized as either having a maximum of greater or fewer than 100 platforms, while independents were categorized as having either greater or fewer than 20 platforms. The eight operators in the "significantly-worse-than-expected" group include one major operating more than 100 platforms and one major with slightly fewer than 100 platforms. If an 80 percent significance level were used, three majors -- each operating more than 100 platforms -- would fall in the "worse-than-expected" classification.

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 total on an operator basis) would fall into this category. The reason for the difference being the large number of platforms operated by the three majors included in the category.

4. CONCLUSIONS

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

We also found only a very small number of "outliers," i.e., operators with either much better or much worse records than one would expect given the number, age, etc. of the platforms they operated, with no predominance by either independents or majors.

Two somewhat contradictory caveats might be attached to this conclusion. The first is that three of the outliers in the "worse-than-expected" end of the distributions were majors operating a relatively large number of platforms, about 26 percent of the total number of platforms during the 1987-1994. Second, given the dramatic drop in the safety score shown in Figure 1, "worse-than-expected" in the 1987-1994 period may not be "so bad" -- at least compared to the earlier (1980-1986) period.

Finally, when comparing independents and majors, it is important not to lose sight of the remarkable decline in the offshore industry's accident rate depicted in Figure 1. Others have shown that workers on offshore platforms today face risks comparable to such occupations as flight attendants or roofers--an equivalence that many would find most surprising [1]. Our own comparisons of majors and independents admittedly are broad, but they certainly do not suggest that history provides much of an argument for tighter OCS regulations if more work offshore were to fall to independent operators.

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Notes

1. One analyst calculated that the probability of a blowout (the event most likely to result in a major oil release) involving a well subject to MMS regulations releasing more than 1,000 barrels was 0.00--with an upper limit of 0.04 [7]. Although this may seem extreme, the total amount of oil spilled during blowout over the 1971 to 1986 period was 840 barrels [6].

2. The simple correlation between the total amount of oil reported to MMS as spilled by each operator and individual operator safety scores was 0.68 for the entire period and 0.60 and 0.42 for the earlier and later periods.

3. The hypothesized relationship being positive according to the conventional wisdom but a central research question for us.

4. Elasticities -- or the percentage change in accidents resulting from a change in operator classification can be generated using the following formula:

$$\xi = e^{\beta} - 1$$

5. The only exception was the variable measuring the percentage of gas wells. In the safety score case we anticipated a positive association (because of a higher potential for explosions and compressor accidents) and in the oil spill case a negative association. We found negative associations in both cases but in neither case was the association statistically significant.