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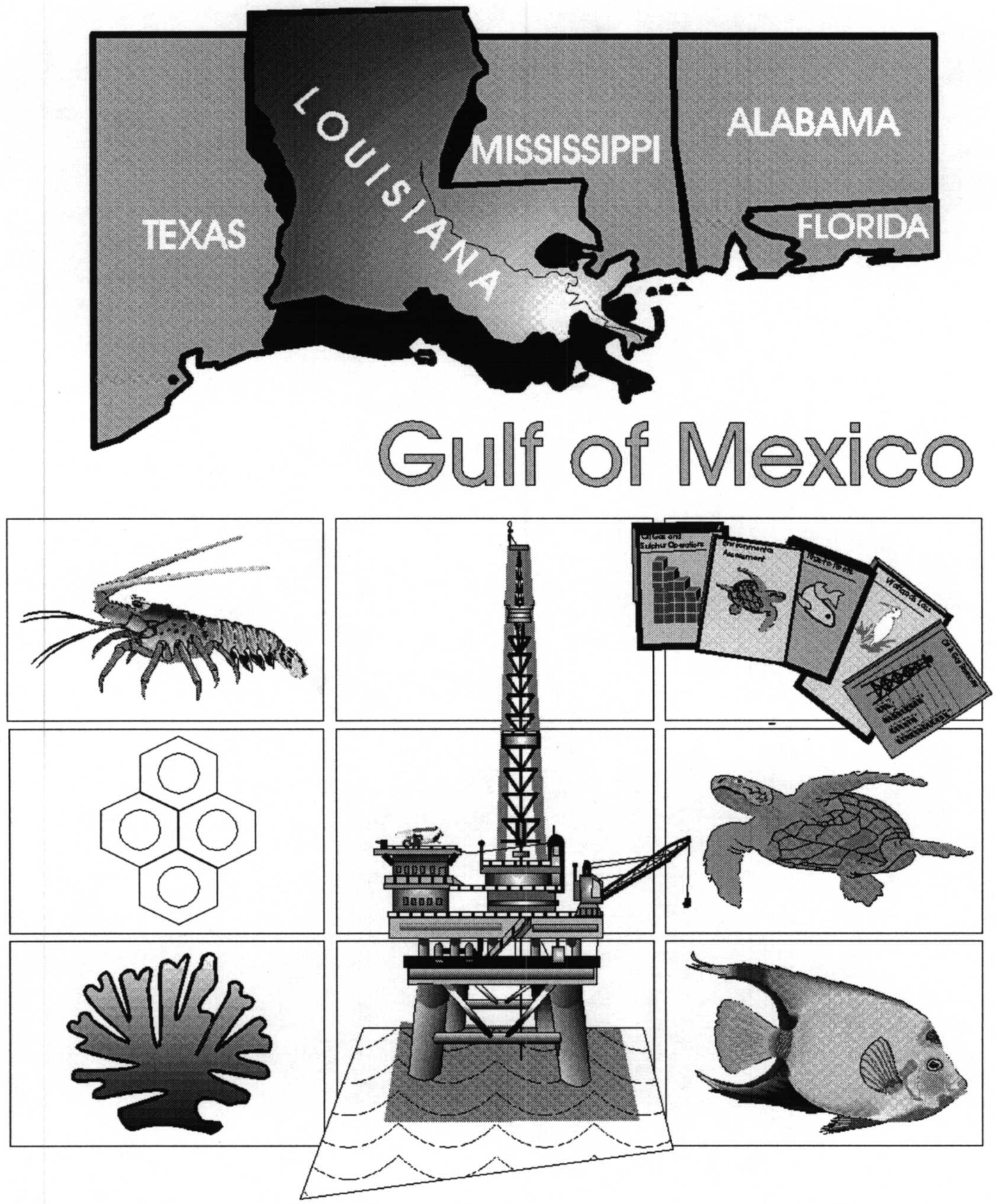
MMS 95-0056

Coastal Marine Institute

Modeling the Structure and Performance of Integrated and Independent Producers in the Gulf of Mexico OCS Region



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

Cooperative Agreement
Coastal Marine Institute
Louisiana State University

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ABSTRACT

Major oil and gas companies are shifting exploration and production (E&P) investment from the United States to foreign countries. As they do so, smaller companies, "independents," are expected to play a more prominent role in domestic E&P. Within both industry and government circles the apprehension is widespread that such a shift from the majors to the independents will cause domestic oil and gas resources to be developed less aggressively and less efficiently.

This project addresses such concerns by attempting to discern and quantify differences in behavior and success among firms of different sizes (majors, large and small independents) operating in the Gulf of Mexico OCS region. Descriptive analysis of data on drilling effort and outcomes on the Gulf of Mexico indicates independents have been both more aggressive and successful than the majors in exploration while the majors have been only moderately more successful than independents in development drilling. Overall, independents appear to have been at least as successful as the majors.

To investigate these differences more carefully, we developed a hydrocarbon model describing the process of adding to reserves through incremental drilling. The model was estimated using data from the Gulf of Mexico OCS region. The model is a combination of an econometric specification of the firm's drilling behavior with the firm's drilling productivity function. The model is used to analyze the effects of taxation, depletion and economic incentives on drilling and drilling productivity. Empirical estimates of the hydrocarbon model of reserve additions confirm the inferences drawn from descriptive analysis. Our measurements indicate that independents respond to market and industry conditions in the same way as do the majors. Thus, we do not believe OCS petroleum resources would be developed less aggressively or less efficiently if the independents were to do relatively more of the search for and development of hydrocarbons in the region.

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ACKNOWLEDGMENTS

This report is based primarily on OCS drilling records made available to the Center for Energy Studies by the Minerals Management Service, New Orleans. Vicki Zatarain and Steve Patkowski of the MMS regional office in New Orleans were very helpful in obtaining this data.

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We also wish to express our appreciation to the participants at the 16th Annual IAEE/USAEE North American Conference in Seattle, Washington, and at the 1995 American Economic Association Annual Meeting in Washington, DC, for their valuable comments on selected sections of this report presented at these meetings.

EXECUTIVE SUMMARY

Major oil and gas companies are shifting exploration and production (E&P) investment from the United States to foreign countries. As they do so, smaller companies, "independents," are expected to play a more prominent role in domestic E&P. Some have questioned whether such a shift from the majors to independents will cause domestic oil and gas resources to be developed less aggressively and less efficiently (Gächter, 1993 and Trench, 1994). This project attempts to discern and quantify differences in behavior and success among firms of different sizes (majors, large and smaller independents) operating on the Gulf of Mexico OCS and to discuss the implications of such differences for future OCS development and for MMS policy and planning.

Our analysis indicates the following:

- Majors and large independents appear to have been about equally enamored of foreign E&P prospects and have responded to them in a similar manner;

- Both descriptive analysis and more discriminating regression analysis of data on drilling effort and outcomes in the Gulf of Mexico indicate independents have been both more aggressive and successful than the majors in exploration while the majors have been only moderately more successful than independents in development drilling. On an aggregate basis, independents have done better.

Thus our summary conclusion is:

- The data we have reviewed provide little evidence to support the speculation that the Gulf OCS hydrocarbon resources would be less aggressively or efficiently developed should independents continue to play a progressively larger role in the search for and development of hydrocarbon resources.

More specifically our descriptive analysis shows:

- If success is measured by barrels of oil equivalent (BOE) added per foot of successful wells drilled, on average, independents were more successful than the majors--adding 265 BOE per successful foot drilled over the 1983 to 1992 period compared to 227 BOE per successful foot drilled for the majors. If total footage drilled, rather than successful footage, is used the difference narrows but independents as a group still do slightly better than majors with 111 BOE compared 106 BOE for the majors.

- Over the past ten years, independent operators accounted for 53 percent of cumulative wildcat permits issued to search for new hydrocarbon reservoirs/fields on the OCS and nearly 70 percent of total exploratory wells drilled on the OCS. Moreover, small independents accounted for more than 40 percent of all exploratory wells drilled by independents and 28 percent of total exploratory wells.

- Independents have been more willing to assume the risk inherent in exploration in the Gulf of Mexico than the majors. More than 50 percent of independents' total drilling effort was exploratory drilling in comparison to the 22 percent for the majors. While one in every four wildcat wells drilled by the majors was successful during the period 1983-1992, one in every three exploratory wells drilled by independents successfully found new reserves during the same period.

Empirical estimates made with our hydrocarbon model confirm the inferences drawn from descriptive analysis in the following manner. We found:

- No statistical evidence of significant differences in the responsiveness of the gross find-rate of hydrocarbon-reserves to technical progress among firms of different sizes operating on the OCS.

- The growing maturity of the Gulf of Mexico OCS more negatively affected reserve additions per foot of well completed among the majors than it affected the independents. The responsiveness of gross find-rate to cumulative drilling (a proxy for the maturity of the Gulf of Mexico OCS) is estimated, on average as -1.12, -0.99 and -0.79, respectively, for majors, large and smaller independents.

- No differences among firms of different sizes in the responsiveness of drilling effort on the OCS to pre-tax net cash flow (economic incentives). Our empirical results suggest a negatively elastic drilling response to taxes among the independents but a negatively inelastic drilling response among the majors.

1. INTRODUCTION

The major integrated companies that explore for, produce, refine and market oil and gas, have historically dominated the petroleum industry in the U.S. But during the past decade these companies have been progressively shifting their exploration and production (E&P) focus to foreign countries. Whether this is the result of geologic factors, such as the maturing of the domestic oil and gas resource base; economic factors, such as higher returns expected from very large new foreign finds and increasing reserve replacement costs in the U.S.; or policy factors, such as federal or state moratoria prohibiting exploration and development in many promising new areas and stricter U.S. environmental requirements, is a matter of considerable debate and conjecture.

Perspectives on the magnitude and permanence--as well as the causes and effects--of this transition are still evolving.

- Is the shift in E&P focus to overseas truly a transition or an illusion created by the major integrated companies reacting more rapidly to an overall decline in the profitability of domestic oil and gas production?

- Are the independents "taking over" or does it just appear so because their share increases as the integrated companies leave?

- Will the independents follow the integrated companies in their pursuit of brighter prospects abroad?

- Can the independents raise the capital required to buy and develop domestic properties that the integrated companies want to sell?

Speculation about the consequences of independent producers replacing integrated companies as the driving force in domestic E&P ranges from quite negative to fairly positive. At the negative end of the range of opinion the argument goes:

- The integrated companies are able to seek higher profits abroad because they are both large enough to hedge the higher risks through diversification and able to wait for the longer payout because they are supported by profits from refining and marketing.

- The reserves that integrated companies are willing to sell are only their least promising ones. They will keep (but not develop as aggressively) their best reserves as a hedge against political uncertainty abroad and protectionist measures that the U.S. Congress may enact at home.

- If major integrated companies withhold or de-emphasize the development of their most promising U.S. reserves, domestic supplies will decrease, import dependence will increase, domestic employment will decline and the U.S. trade deficit will grow.

At the positive end of the continuum, the more optimistic scenario is:

- Integrated companies are less efficient than independents in developing reserves and are being "forced" abroad because domestic development costs are rising.

- In time, the market will work. It will allocate reserves to those who can develop them more profitably.

- As the integrated companies leave, independent producers will buy their properties and develop them more efficiently.

Predicting where the future will eventually appear in this range of speculation is complex but important from a public policy as well as a strictly business perspective. Some analysts have speculated that the shift from the majors to independents will slow the pace of exploration drilling as opposed to development drilling. And, at a more operational level, in response to concerns about the financial viability and stability of independents, MMS reports that it "is considering several steps that will insure that [independent] producers have the resources to support offshore drilling" (Gächter, 1993). Thus, important aspects of national energy policy will be affected by the consequences of this transition. Despite the prominence of these questions in both industry and public policy circles, they have inspired little comprehensive empirical analysis; hence the motivation for this project.

The report is organized into five sections and an executive summary. The following section presents indicators of domestic and foreign activity for independents and majors. The third section compares exploration and development drilling records of majors and independents in their search for petroleum resources in the Gulf of Mexico OCS region since 1978. The fourth section, develops, estimates and exercises an economic model of hydrocarbon reserve additions to 1) test the hypothesis that majors explore for and develop petroleum resources more efficiently or aggressively on the Federal OCS than independents and 2) study differences in the responsiveness of drilling and drilling outcomes among the majors and independents to changes in economic factors, depletion, and taxes. The final section summarizes the principal conclusions and the authors' recommendations.

2. DOMESTIC EXPLORATION AND PRODUCTION: EXODUS OF MAJORS AND TAKEOVER BY INDEPENDENTS?

How persuasive is the evidence that the majors are leaving the development of domestic oil and gas reserves in favor of foreign opportunities? Will the magnitude of this exodus expand the independents share of domestic E&P significantly--especially on the OCS?

The data available to characterize these trends over the 1987 to 1992 period, in our view, implies that although the share of E&P undertaken by independent operators is growing, the heralded "take over" of the domestic oil and gas producing industry by the independents may be an exaggeration.

2.1 - Classifying majors and independents

For analytical purposes, oil and gas operators operating in the U.S. have been classified into three groups--the 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 report 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 criteria.

- Smaller independent firms are those appearing on the OGJ list of the largest 300 firms but do not have assets of $500 million or more. Data on assets are only available for publicly traded companies. Thus our definition, alone, would classify all privately held companies as "smaller independents." We contacted several such companies but each said "smaller independent" was the appropriate designation.

It should be noted that this classification is based on total--not OCS per se--activity. Some firms classified as "small independents" under this classification were responsible for a larger share of OCS production than some majors. A list of the firms included in each category is given in Appendix A.

2.2 - Measures of Foreign and Domestic Activity and Success

Operating data for oil and gas firms of different sizes are presented in Table 1. The data reported in the table are aggregate, national-level data, but they are useful for comparing the relative emphasis of foreign and domestic E&P strategies among firms of different sizes--majors and independents. Although these comparisons provide a useful scale and perspective, they may not be representative of trends in particular regions. For example, Alaska produces about 25 percent of the oil produced in the United States and almost no Alaskan oil is produced by independent producers. However, about 58 percent of the oil and 60 percent of the gas produced in Louisiana (excluding Federal OCS production) comes from independent producers. Thus changes in the relative shares of majors and independents in Gulf Coast activity may have important consequences for that region that may be obscured in the national data.

Table 1 shows three-year moving averages summarizing operating and performance data on domestic and foreign exploration and development expenditures, oil production, gas production, oil and gas reserve additions, hydrocarbon replacement ratio, reserve purchase cost, finding costs and expenditure effectiveness for individual domestic oil and gas companies (Arthur Anderson and Co., 1984, 1990 and 1993). The data are grouped by majors and independents and, for most categories, are shown separately for domestic and foreign operations.

Figure 1, which depicts the data summarized in the first section (A) of Table 1, shows total exploration and development (E&D) expenditures, which have frequently been used to describe the apparent "take over" of domestic oil and gas activities by the independents. The trends seem clear and dramatic. Over the six-year period domestic expenditures for E&D by the majors declined by 34 percent while those by the independents increased by about 12 percent. As a consequence of this disparity, the majors' share of total, domestic E&D expenditures declined by over 10 points, falling from 77 percent in 1987 to 66 percent in 1992.

However, data on E&D spending on foreign prospects, also shown in Figure 1, indicates that the majors and the independents have both responded aggressively to opportunities abroad. Expenditures by majors increased by an impressive 113 percent, but expenditures by the independents also increased by a healthy 73 percent.

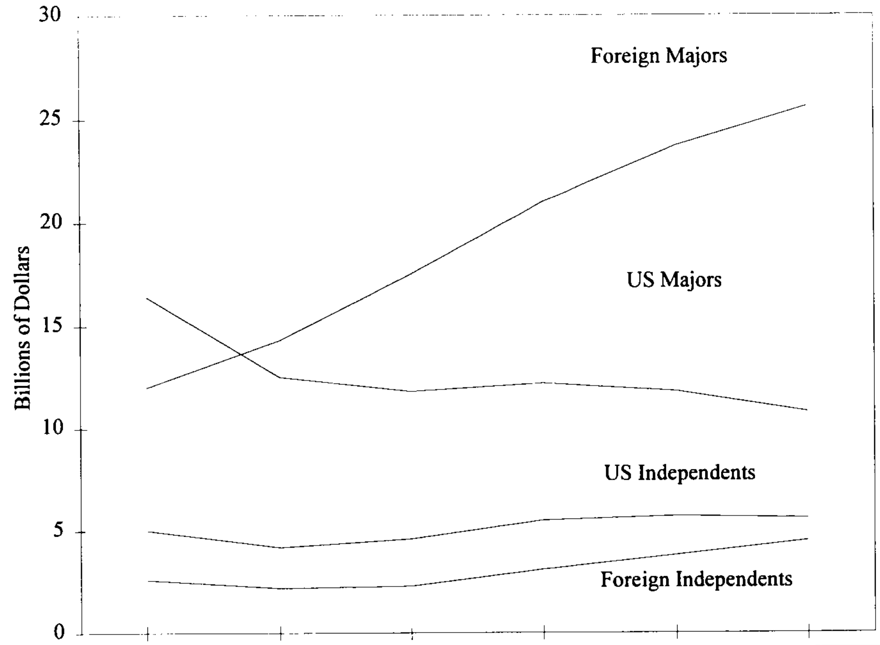
Other sections of Table 1 show trends in domestic and foreign oil and gas production and additions to reserves. Two useful "bottom line" measures, however, are given in sections (E) (showing the production replacement ratio) and (H)--recording the reserves added per $1,000--in E&D expenditures.

Table 1. Measures of the Operating Performance of U.S. Oil and Gas Producers (three-year averages)

	1987	1988	1989	1990	1991	1992
A: E & D Expenditures (Billion $)						
U.S.:						
Majors	16.4	12.5	11.8	12.2	11.8	10.8
Independents	5.0	4.2	4.6	5.5	5.7	5.6
Total	21.4	16.7	16.4	17.6	17.5	16.4
Foreign:						
Majors	12.0	14.3	17.5	21.0	23.7	25.6
Independents	2.6	2.2	2.3	3.1	3.8	4.5
Total	14.6	16.5	19.8	24.1	27.5	30.0
B: Oil Production (Million Barrels)						
U.S.:						
Majors	2,015	1,971	1,901	1,815	1,751	1,694
Independents	312	300	291	289	296	302
Total	2,327	2,271	2,192	2,104	2,047	1,996
Foreign:						
Majors	1,970	2,046	2,111	2,209	2,259	2,323
Independents	202	206	219	250	295	328
Total	2,172	2,252	2,330	2,459	2,554	2,651
C: Gas Production (Bcf)						
U.S.:						
Majors	6,703	6,516	6,565	6,612	6,660	6,649
Independents	2,777	2,895	3,092	3,336	3,548	3,667
Total	9,480	9,411	9,657	9,948	10,208	10,256
Foreign:						
Majors	3,898	4,396	5,038	5,874	6,435	6,927
Independents	714	776	929	1,095	1,237	1,324
Total	4,612	5,172	5,968	6,969	7,672	8,251
D: Oil and Gas Additions (Million BOE)						
U.S.:						
Majors	1,517	1,363	1,451	1,615	1,610	1,465
Independents	553	570	640	770	765	780
Total	2,070	1,932	2,091	2,385	2,375	2,245
Foreign:						
Majors	1,607	1,549	1,738	2,399	2,918	3,196
Independents	266	286	323	418	477	530
Total	1,874	1,835	2,061	2,817	3,395	3,727

Table 1(contd.)

E: Oil Production Replacement Ratio						
U.S.:						
Majors	77	76	88	81	77	68
Independents	62	67	95	110	98	94
Weighted Average	75	75	89	85	80	72
Foreign:						
Majors	100	99	118	123	117	116
Independents	100	108	115	114	116	119
Weighted Average	100	100	117	122	117	117
F: Reserve Purchase Cost ($/BOE)						
U.S.:						
Majors	5.37	3.92	4.80	5.07	4.82	3.37
Independents	5.58	4.94	4.72	4.41	4.15	4.06
Weighted Average	5.12	4.48	4.71	4.63	4.40	3.98
Foreign:						
Majors	5.93	5.91	3.37	4.29	4.44	4.16
Independents	5.17	3.92	4.78	3.93	3.42	2.79
Weighted Average	4.56	4.40	3.71	3.89	3.93	3.67
G: Finding Costs ($/BOE)						
U.S.:						
Majors	10.83	9.20	8.11	7.54	7.31	7.37
Independents	8.98	7.32	7.18	7.10	7.49	7.23
Weighted Average	10.34	8.64	7.83	7.39	7.37	7.32
Foreign:						
Majors	7.44	9.23	10.09	8.77	8.11	8.00
Independents	9.77	7.68	7.13	7.42	8.03	8.42
Weighted Average	7.77	8.99	9.62	8.57	8.10	8.06
H: Expenditure Effectiveness (BOE/$000)						
U.S.:						
Majors	92	109	123	133	137	136
Independents	111	137	139	141	133	138
Total	97	116	128	135	136	137
Foreign:						
Majors	134	108	99	114	123	125
Independents	102	130	140	135	125	119
Total	129	111	104	117	123	124



	1987	1988	1989	1990	1991	1992
US Majors	16.4	12.5	11.8	12.2	11.8	10.8
US Independents	5.0	4.2	4.6	5.5	5.7	5.6
Foreign Majors	12.0	14.3	17.5	21.0	23.7	25.6
Foreign Independents	2.6	2.2	2.3	3.1	3.8	4.5

Note: Values are three-year moving averages

Figure 1. E&D Expenditures, Domestic and Foreign, by Majors and Independents, 1987 to 1992

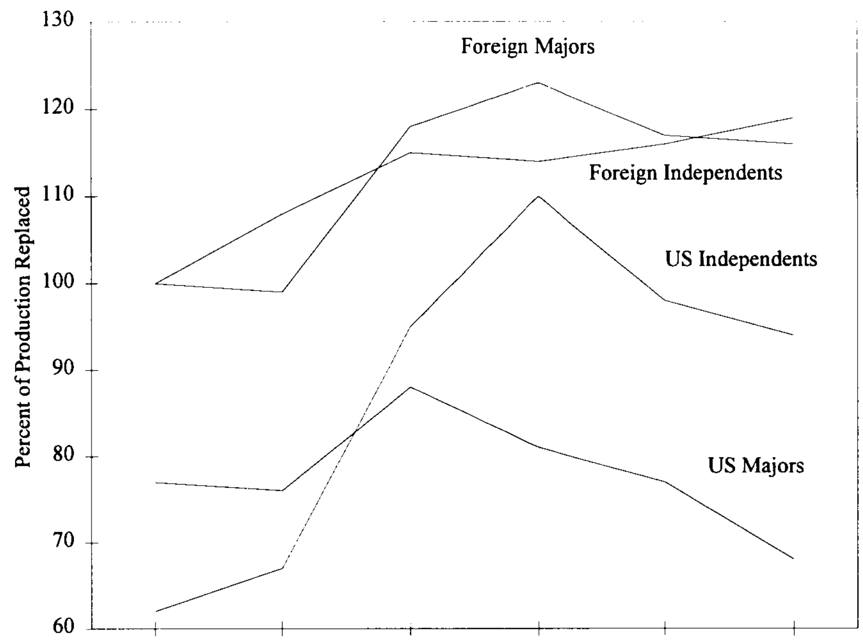
The extent to which new reserve additions, domestic and foreign, have kept pace with production is depicted in Figure 2. On average the additions to reserves by the majors amounted to about 75 percent of domestic production over the period, while independents, on average, replaced 87 percent of their production. Further, the independents' domestic replacement rate was clearly on an increasing trend over the period. But in the foreign sector, both the majors and the independents added foreign reserves more rapidly than they produced foreign oil--each showing a closely correlated, average replacement ratio of 112 percent increasing with time.

Figure 3 shows trends in "expenditure effectiveness" which is simply reserve additions per $1,000 of E&D expenditures measured in barrel of oil equivalent. Differences between the two groups of firms seems to narrow with time and the averages of the last three years are clearly too close to support any generalizations about differences in relative efficiencies--regarding either domestic or foreign activity.

The data reviewed in Table 1 and illustrated in Figures 1, 2 and 3, suggest that, at least from a national perspective, the heralded "take over" of the domestic oil and gas producing industry by the independents may be an exaggeration. Independents are doing relatively more domestic E&D, but their increased share appears to be more reflective of the decline in E&D spending by the majors than of increased spending by independents.

Moreover it is not clear how much of the apparent "take over" is a temporary or cyclical phenomenon rather than a longer-term, structural change in the industry. Some independents have announced that they have been disappointed with foreign initiatives and plan to refocus on domestic production (Fan, 1995). Others believe structural change shifting the relative importance of majors and independents will continue (Walsh, 1994). Still others argue that more fundamental geologic and price concerns will perpetuate the trends of the last 25 years for the foreseeable future (Trench, 1994). However, all the measures we have analyzed indicate that the independents have been just as aggressive as the majors in pursuing reserves and production abroad. Thus, in the aggregate, the evidence is not very persuasive that the independents are pursuing strategies tilted toward domestic production while the majors shift their activity abroad.

Finally, it is important to note that the sheer magnitude of the proportion of activity attributable to the majors in most of the categories reviewed, means that the majors will continue to dominate domestic activity for the foreseeable future. The category that comes closest to being an exception to this rule is domestic gas production where the majors' share of production has fallen from about three-fourths to two-thirds of the total. Thus, although independents are playing an increasingly important role in <u>both</u> domestic and foreign sectors, the strategies and performance of the majors will remain a key focus for MMS and other energy analysts for some time to come.

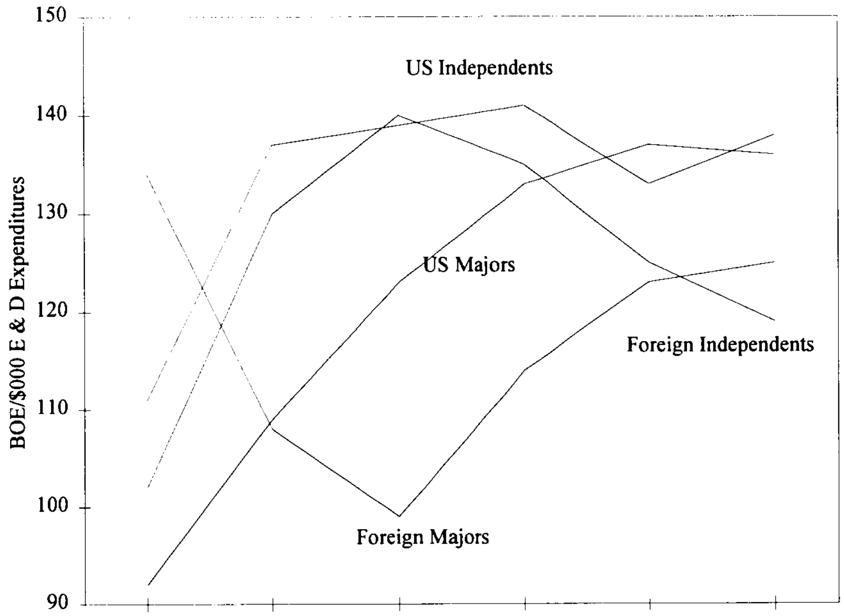


	1987	1988	1989	1990	1991	1992
US Majors	77	76	88	81	77	68
US Independents	62	67	95	110	98	94
Foreign Majors	100	99	118	123	117	116
Foreign Independents	100	108	115	114	116	119

Note: Values are three-year moving averages

Source: Table 1

Figure 2. Oil Production Replacement Ratios, Domestic and Foreign, by Majors and Independents, 1987 to 1992



	1987	1988	1989	1990	1991	1992
US Majors	92	109	123	133	137	136
US Independents	111	137	139	141	133	138
Foreign Majors	134	108	99	114	123	125
Foreign Independents	102	130	140	135	125	119

Note: Values are three-year moving averages

Source: Table 1

Figure 3. Effectiveness of E&D Expenditures, Domestic and Foreign, by Majors and Independents, 1987 to 1992

3. COMPARING THE EXPLORATION AND DEVELOPMENT DRILLING RECORDS OF MAJORS AND INDEPENDENTS

Would the pace or efficiency of the development of oil and gas resources on the OCS in the Gulf of Mexico be hindered if proportionately more activity were undertaken by independents and less by the majors? To answer this question we first compiled and analyzed descriptive statistics on the relative performance of these groups over the past decade. Then, as described in the next section of the report, we constructed and exercised an econometric model of the hydrocarbon reserve additions process.

Raw data on petroleum industry activity and outcomes, for firms searching for hydrocarbon resources on the Gulf of Mexico OCS were made available from the MMS data file in New Orleans. Using this data, industry activity indicators and performance measures were derived, organized and analyzed to characterize the behavior and performance of majors and different groups of independents over the past decade. Subsequently, each group of operators were compared in terms of their share in: a) permits issued, b) wells drilled, c) footage drilled, d) successful wells completed and e) footage of successful wells completed. Where appropriate we also compared these indicators by a) well category (exploration or development), and b) well type (oil or gas), to identify any significant differences among the groups and areas. Tables 2 and 3 present, for each group of operators, indicators drawn from these measures for the 10-year period 1983 to 1992. Table 2 records the cumulative shares in permits, wells drilled, footage drilled, successful wells completed and footage of successful wells drilled in the Gulf of Mexico OCS region.

3.1 - Geological and Geophysical Permits

Data from the Minerals Management Service (MMS) of the U.S. Department of the Interior show a decline in the number of oil and gas firms that were issued at least one geological and geophysical (G&G) permit to search for new petroleum reservoirs on the OCS. In 1981, 67 operators obtained permits; but in 1992 the number of operators issued such permits was down by 25 percent to 50 operators. Thirty-six of the 50 operators actively exploring for hydrocarbons were independent operators. As shown in Table 2, 53 percent of cumulative geological and geophysical permits issued to oil and gas operators over the past ten years for OCS activity were issued to independents (22.1 percent for large independents and 31.2 percent for smaller independents).

Figure 4 shows the three-year moving average trend in the distribution of geological and geophysical permits issued to oil and gas producers in the Gulf of Mexico OCS region. The share of permits issued to majors declined from a peak of 59 percent in 1980 to a low of 41 percent in 1986. Since 1986, however, the majors's share of permits has increased and in 1992 was about 50 percent of the total permits issued in the region.

Table 2. Share of Firms in Upstream Oil and Gas Activity on the Gulf of Mexico OCS 1983-1992

OCS Activities	Majors	Independents			Total OCS
		Small	Large	Total	
Percent:					
Total Permits Issued	46.7	31.2	22.1	53.3	100.0
Wells Drilled:					
Exploratory	30.6	27.7	41.7	69.4	100.0
Development	57.8	13.1	29.1	42.2	100.0
Total	48.9	18.1	33.0	51.1	100.0
Footage Drilled:					
Exploratory	43.6	21.4	35.0	56.4	100.0
Development	61.3	11.8	26.8	38.7	100.0
Total	53.1	16.3	30.6	46.9	100.0
Successful Wells:					
Exploratory	24.0	28.6	47.4	76.0	100.0
Development	60.0	12.9	27.1	40.0	100.0
Total	54.1	15.5	30.4	45.9	100.0
Successful Footage:					
Exploratory	27.9	27.6	44.4	72.1	100.0
Development	62.4	11.7	25.9	37.6	100.0
Total	55.8	14.7	29.4	44.2	100.0

Table 3. Performance Measures of Oil and Gas Producers on the Gulf of Mexico OCS 1983-1992

OCS Indicators	Majors	Independents			Total
		Small	Large	Total	OCS
Exploratory Effort:					
Wells	22.3	54.4	44.9	48.3	35.5
Footage	37.8	60.5	52.7	55.4	46.0
Success Ratio: Wells					
Exploratory	25.5	33.6	37.0	35.6	32.5
Development	77.1	73.5	69.1	70.5	74.3
Total	67.6	52.4	56.2	54.9	61.1
Success Ratio: Footage					
Exploratory	11.8	23.8	23.4	23.6	18.4
Development	68.5	66.4	65.0	65.4	67.3
Total	46.7	40.2	42.8	41.9	44.4
Drilling Productivity:					
Oil (Million Bbl)	1,547	293	473	766	2,314
Gas (Bcf)	18,632	8,237	12,676	20,913	39,544
Drilling Effectiveness:					
Oil (Bbl/Ft)	103	131	143	138	112
Gas (Mcf/Ft)	1,281	1,093	1,083	1,087	1,171
Hydrocarbon (BOE/Ft)	227	312	242	265	244

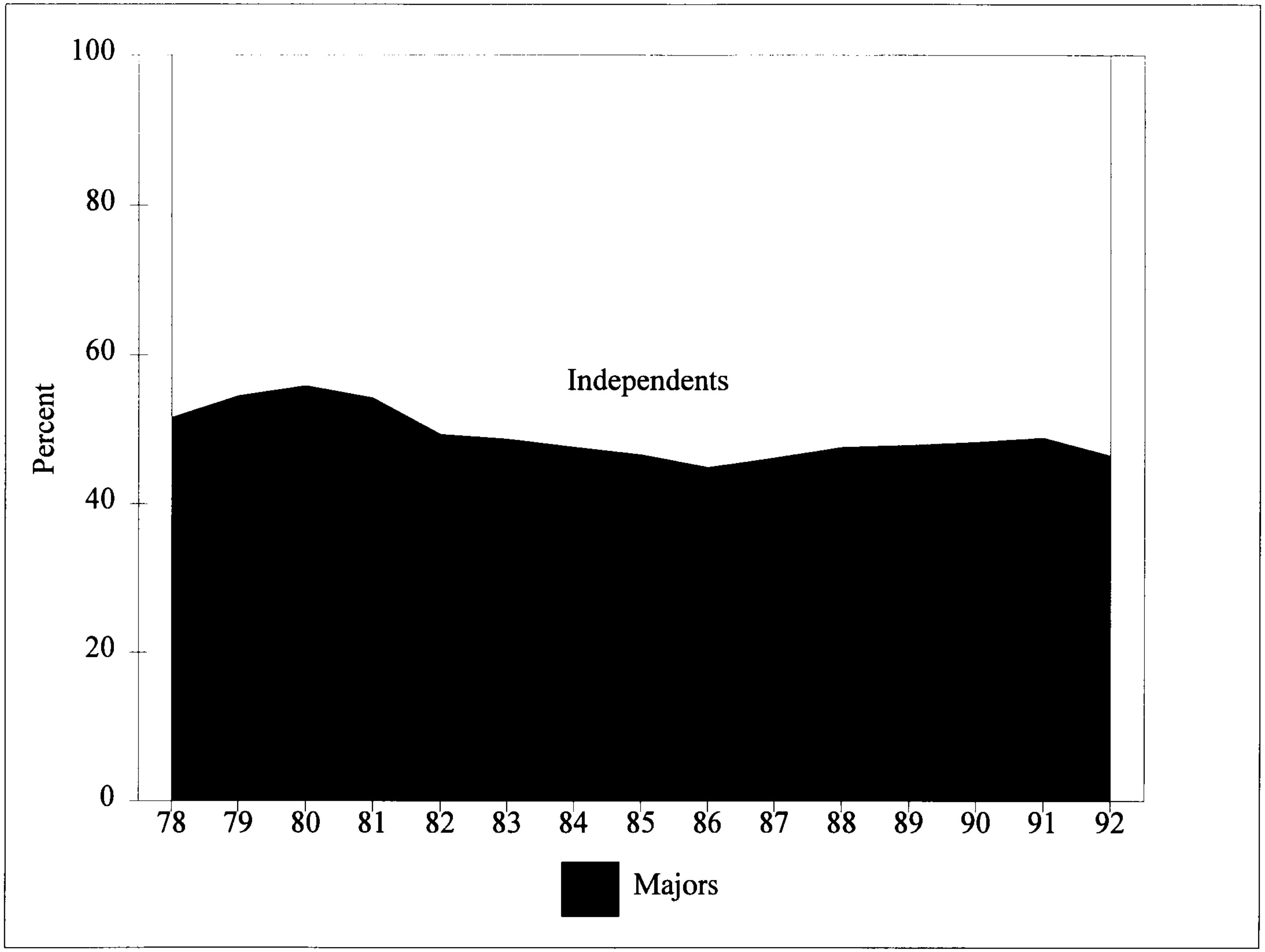


Figure 4. Shares in Geological and Geophysical Permits Issued on the Gulf of Mexico OCS

3.2 - Drilling Activity

Over the 10-year period 1983 to 1992, independent operators accounted for nearly 70 percent of the exploratory wells drilled on the OCS. The major oil and gas operators drilled more development wells on the OCS than the independents within the last 10 years and were slightly more successful than independent operators--accounting for 58 percent of the total development wells drilled and 60 percent of successful development wells.

If drilling records are compared on the basis of footage drilled, then 1) the majors' share in exploratory drilling activity increases from 31 to 44 percent--reflecting the fact that exploratory wells drilled by the majors, on average, were deeper than independents' wells during this period; and 2) the majors' advantage in development drilling increases modestly as well. Trends in the shares of independents and majors in total exploratory footage and development footage are presented in Figures 5 and 6.

As evident in Figure 5, at least in relative terms, the independents have become more willing to undertake exploratory drilling than the majors since 1987. Prior to 1987, the majors' share in exploratory footage drilled averaged above 50 percent, compared to their less than 40 percent share from 1989-1992. We should emphasize that exploratory effort is credited to the designated operator when more than two operators are jointly involved to avoid double counting. Figure 6 shows that the majors' share of total footage for development wells drilled in the Gulf OCS peaked in 1988 at 68 percent and had fallen to about 56 percent by 1992.

3.3 - Drilling Performance

The performance of each group of operators is measured by: 1) exploratory effort as percent of total drilling effort, 2) wildcat success rates, 3) drilling effectiveness (finding rate) and 4) drilling productivity (recoverable reserves added due to new drilling). The 10-year performance measures for each group of operators are summarized in Table 3.

3.3.1 - Exploratory Effort: The term "exploratory effort" here means the ratio of exploratory drilling to total drilling in a given period. In the 10-year period 1983-1992, approximately one in every three hydrocarbon wells drilled on the Gulf OCS was an exploratory well. The major oil and gas operators made less of an exploratory effort during the period than either of the two categories of independent operators. If exploration effort is measured by exploration footage drilled as a fraction of total footage drilled, the major's effort improves from 22 percent to 38 percent, but is still below the 55 percent level achieved by independents as a group.

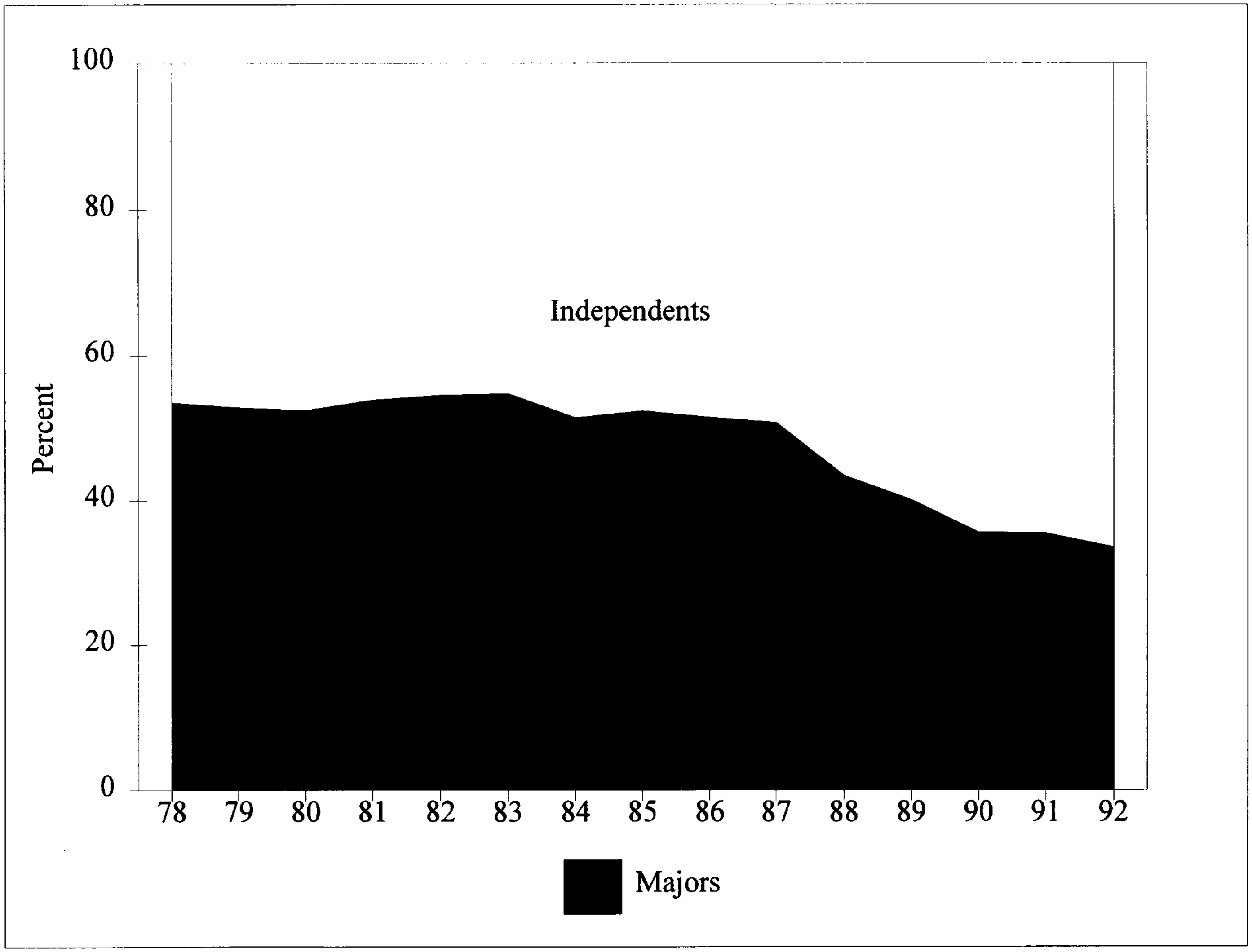


Figure 5. Shares in Total Exploratory Footage on the Gulf of Mexico OCS

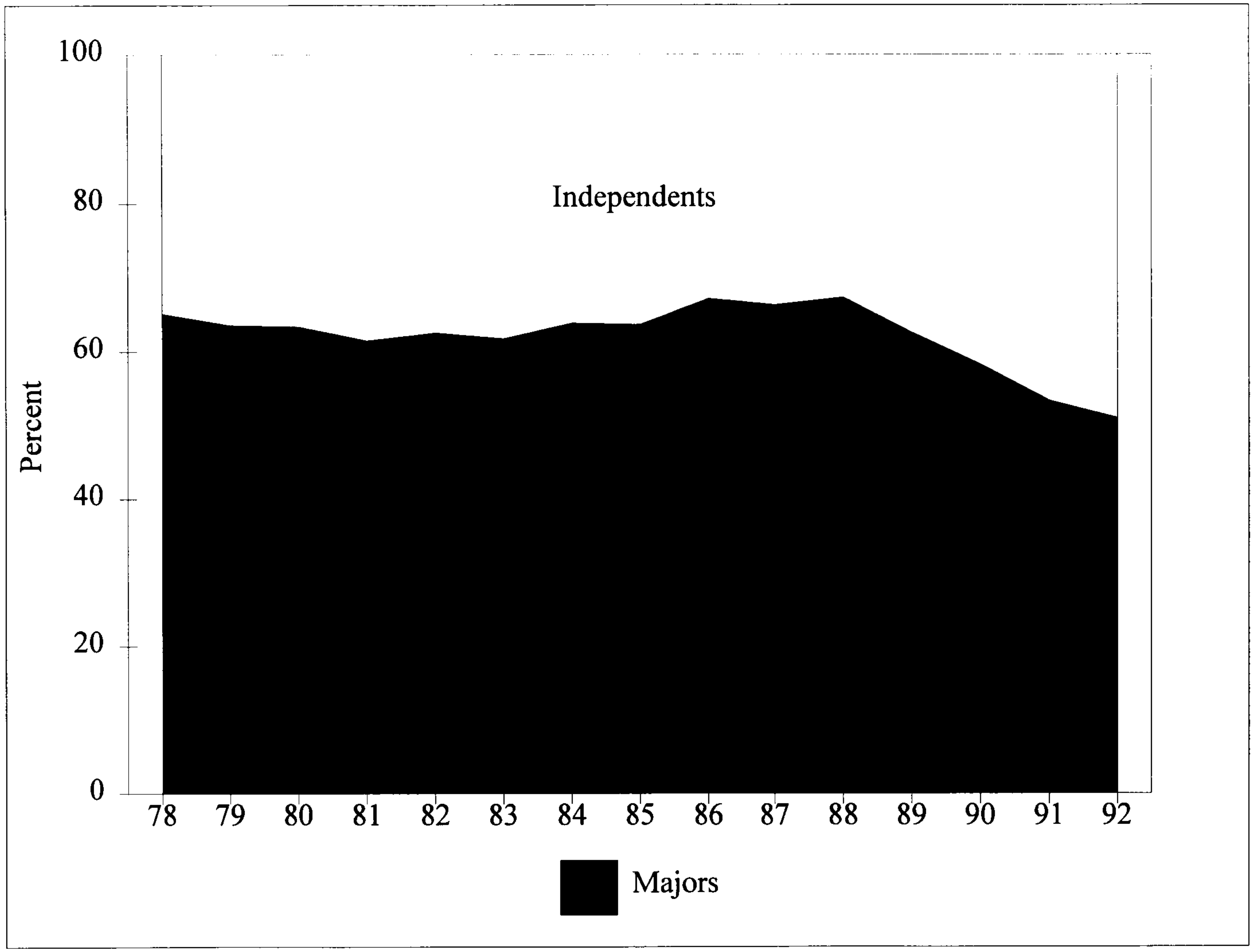


Figure 6. Shares in Total Development Footage on the Gulf of Mexico OCS

Figure 7 shows that the trend in majors' exploratory effort--exploratory footage drilled as a fraction of total footage--follows a similar pattern to that of the independents prior to 1983. However, since 1983, the independents effort has increased far more than the majors'. In fact, from 1985 to 1992 independents' effort doubled in relative terms, increasing from 30 percent to a peak of more than 60 percent in 1989, whereas the majors' effort only increased from 20 percent to a peak of less than 40 percent during the period.

3.3.2 - Exploratory Success: Not only have independents been willing to assume the higher risks inherent in exploration, independents also have enjoyed more success over the past decade in their search for new hydrocarbons in the Gulf of Mexico. As shown in Table 3, whereas approximately one in every four exploratory wells drilled by majors were successful in adding new reserves, one in every three exploratory wells drilled by independents were successful during the 1983 to 1992 period.

Trends in successful footage as a share of total exploratory footage are presented in Figure 8. Prior to 1985, majors were relatively more successful than the independents in exploratory drilling. However, since 1985 independents have not only had more exploratory successes than the majors, but the independents' success rate seem to have improved significantly relative to the majors.

3.3.3 - Development Success: Figure 9 shows the majors have been marginally but consistently more successful in development drilling than independents considered as a group. Although in the final part of the period the success rate for the majors was rising while the overall success rate among the independents was declining, since 1987 both have risen more or else in tandem. Over the period, the major's success rate for development drilling on average was approximately 77 percent compared to the 71 percent success rate for independents as shown in Table 3. It is also evident from the table that large independents had a higher success rate in development drilling than the smaller independents.

3.3.4 - Drilling Effectiveness: The lower part of Table 3 reports drilling effectiveness (additions to reserves per foot of successful wells drilled) for oil, gas and total hydrocarbons. On average, for every foot of successful wells drilled by the majors on the OCS, 227 barrels of oil equivalent (BOE) of new hydrocarbons were added to original recoverable hydrocarbons in-place during the period 1983-1992. Whereas 265 BOE of hydrocarbons were added for every foot of successful wells drilled by all the "independents" during the same period. The two independent operator categories were more successful than were the majors, with the independents as a group adding about 18 percent more hydrocarbons per foot of successful well drilled than the majors over the 10-year period. But while independents in each category were more successful than the majors in adding oil reserves, the majors were more successful at adding gas reserves.

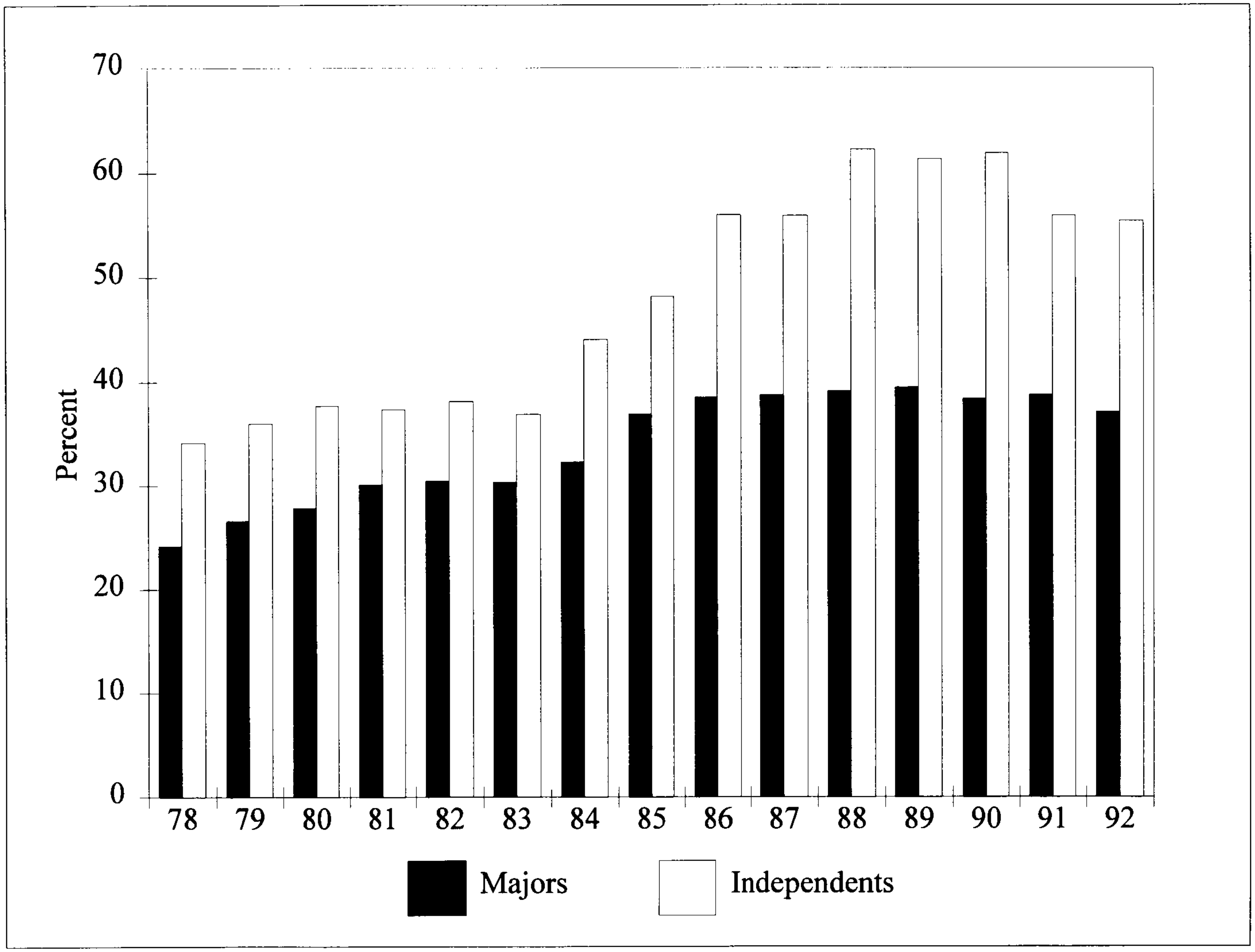


Figure 7. Exploratory Footage as a Share of Total Footage on the Gulf of Mexico OCS

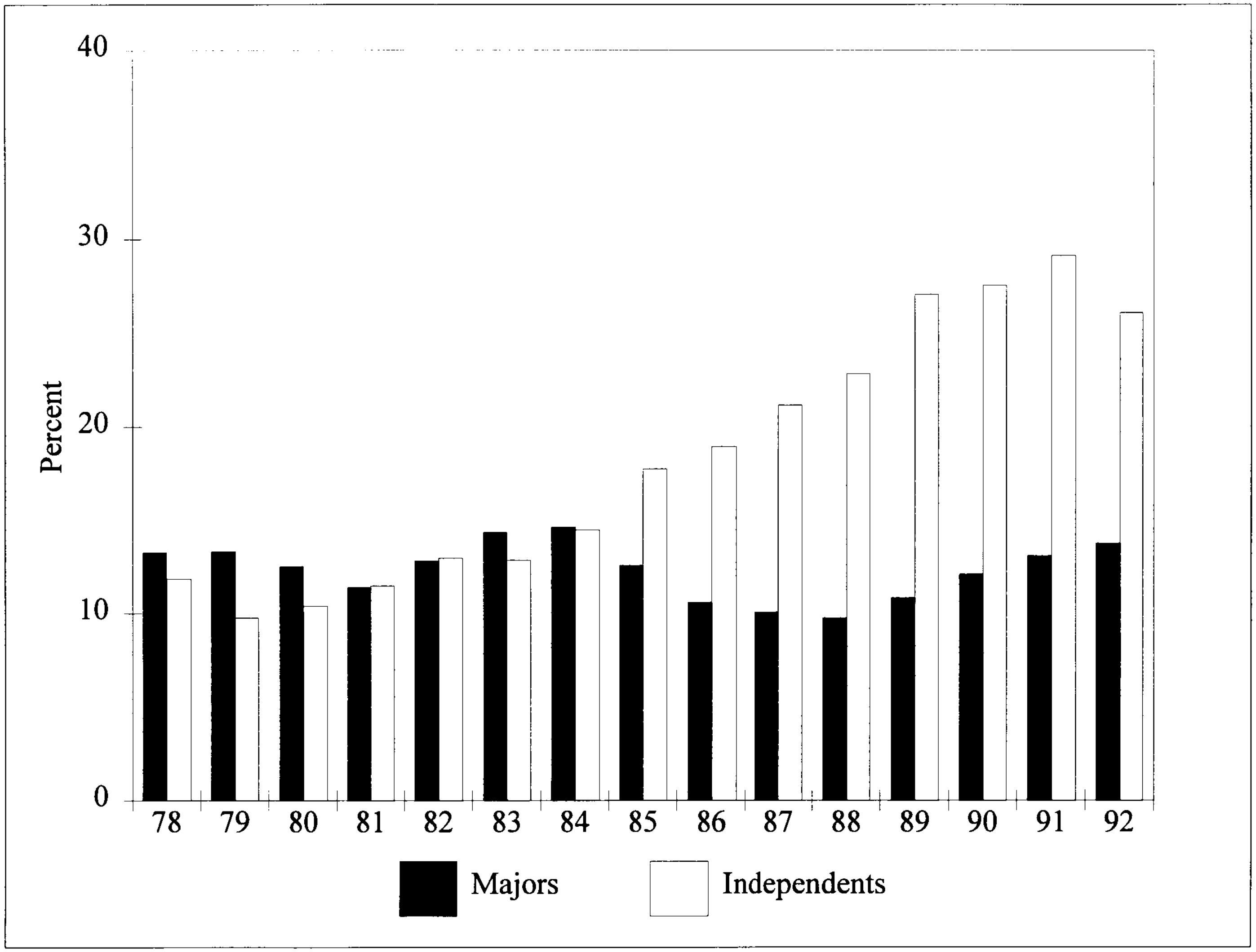


Figure 8. Successful Exploratory Footage as a Share of Total Exploratory Footage on the Gulf of Mexico OCS

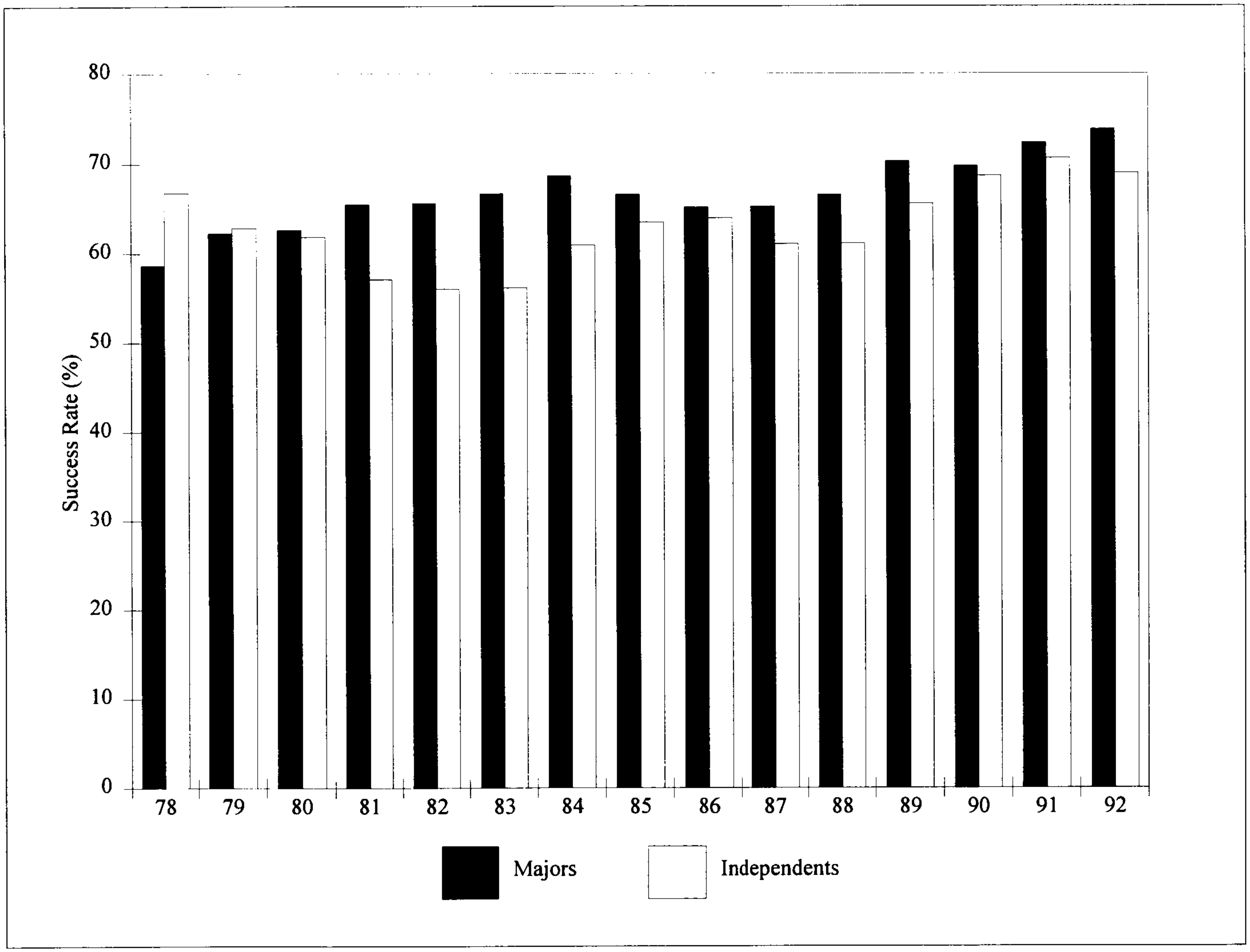


Figure 9. Successful Development Footage as a Share of Total Development Footage on the Gulf of Mexico OCS

The time path of drilling effectiveness --gross finding rate--is presented in Figure 10. The figure shows that independents have generally added more reserves per successful well-footage drilled than the majors every year since 1981. However, the figure also shows a declining overall trend in gross finding rate among both the majors and the independents since 1979, despite the rising success rates shown in Figures 8 and 9. The fact that success rate rises and gross find rate declines is indicative of the fact that the size of new finds is getting smaller as large and easy to find reserves are normally expected to be discovered earlier in the exploration and development process.

3.4 - Implications

The data we have reviewed provide little evidence to support the apprehension that the Gulf OCS hydrocarbon resources would be less aggressively or efficiently developed should independents--even smaller independents--continue to play a progressively larger role in the search for and development of hydrocarbon resources on the Gulf OCS.

Simple descriptive analysis of upstream oil and gas industry activity indicators suggests independents are doing more exploration on the OCS than the majors by nearly a 2:1 ratio. Independents are also more successful in exploratory drilling on the Gulf than the majors especially since the collapse of the world oil prices in 1986. Although not as effective as the majors at adding new gas reserves, independents discovered as many reservoirs as the majors and discovered about the same amount of hydrocarbon reserves as the major operators on the OCS since 1983.

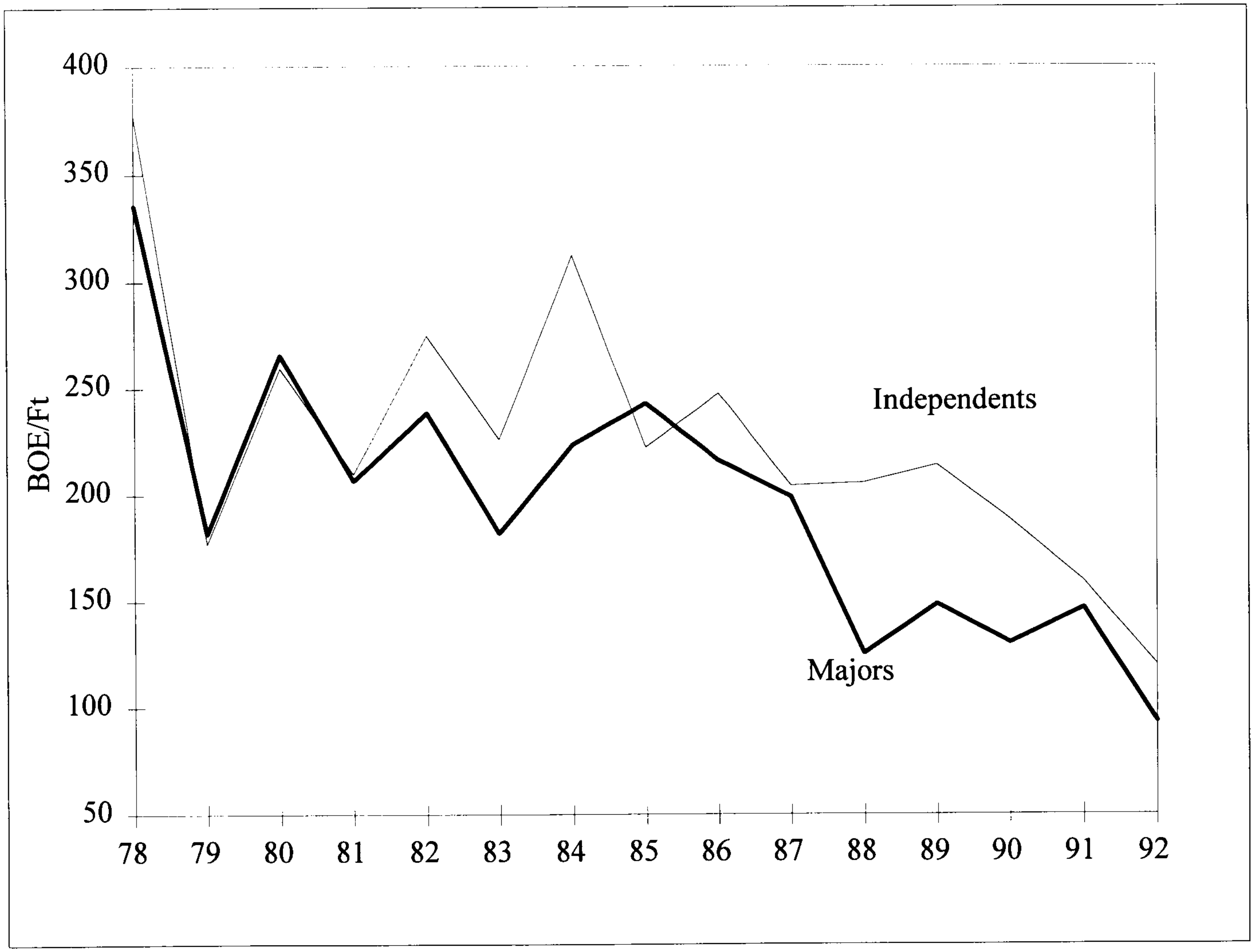


Figure 10. Gross Finding Rate on the Gulf of Mexico OCS

4. A MODEL OF HYDROCARBON RESERVE ADDITIONS

The comparison of the behavior and performance of firms of different sizes operating on the Gulf OCS presented earlier in Section 3 are quite broad and cover a period of major structural change within the industry, both domestically and internationally. Thus, in this section we present a hydrocarbon model of reserve additions that is capable of quantifying the significant differences in the way each group of operators' drilling activity and the subsequent drilling outcomes respond to changes in the determinants of reserve additions--drilling effort, technology change, changes in the economic, market and regulatory environments.

4.1 - Modeling Literature

A variety of crude oil and natural gas supply models have been formulated and implemented since the early 1970s using the theoretical and analytical methods of several disciplines including petroleum engineering, economics, geology, operations research, and management science. The more prominent of these models and studies may be loosely classified as either geologic-engineering (G-E)--life cycle, rate-of-effort, play analysis and discovery process--or econometric models (Adelman et al., 1983). Walls (1992) provides a thorough survey of existing petroleum and natural gas supply studies and modeling approaches.

The basic premise of most G-E models is that the rate of petroleum discovery in a petroleum region or district tends to decline as exploration and development drilling proceeds. These models do not have much economic content, but use geological and engineering information extensively to try to capture the subtleties of petroleum engineering and geological characteristics of petroleum exploration, development and depletion processes. Examples of the early G-E models include: Arps and Roberts (1958), Hubbert (1974), Drew et al. (1980), Attanasi et al. (1981). Cleveland and Kaufmann (1991) made a more recent effort to include economic factors in the Hubbert (1974) modeling framework.

Econometric models and studies, on the other hand, rely on the reasoning that higher economic incentives will lead to more new drilling, which will consequently lead to more new reserve additions at a decreasing rate, in part, *ceteris paribus*, due to diminishing returns. The more widely cited oil and natural gas supply studies and models include Erickson and Spann (1971), Khazzoom (1971), MacAvoy and Pindyck (1973), Pindyck (1978a), Kim and Thompson (1978), and Eckbo et al. (1978). Nearly all of these econometric models are national in scope (or at best have very broad regional divisions), use aggregate annual data to estimate model equations, and yield unreliable predictions of future regional drilling activity and drilling outcomes in terms of new reserve additions.

Pindyck (1978b) attributed the weakness of the traditional aggregate approaches to modeling the supply of oil and gas to the fact that aggregation of oil and gas data across distinctive geologic provinces may obscure the effects of economic and policy variables on the pattern of E&D activities.

Pindyck suggested that it would be more fruitful to model E&D outcomes at the micro level of individual pools, fields, or geological provinces. Such models would be able to capture not only the petroleum engineering and geological characteristics of petroleum supply process, but also the economic and policy incentives motivating producers to search for and development petroleum resources.

4.2 - Model Framework

The hydrocarbon modeling framework adopted in this study is a combination of an econometric model of drilling effort with a drilling process model that determines the corresponding drilling outcomes. This approach is similar to the one proposed in Walls (1992) and used in Walls (1994) to model oil and gas supply on the Gulf of Mexico OCS using aggregate OCS data. Here, we estimate model parameters using pooled data organized by type of firm--major, large independents and smaller independents--across time.

Conceptually, the hydrocarbon model begins with an identity that defines drilling productivity (gross hydrocarbon reserve addition) in a given period as the product of the probability of a successful drilling effort (success rate), incremental drilling effort during that period, and the effectiveness of a successful drilling effort at adding new reserves (find rate). That is,
where

$$G_t = \lambda_t * y_t * x_t \tag{1}$$

G_t = hydrocarbon reserve additions at time t;
y_t = effectiveness of drilling in adding new reserves, measured in terms of recoverable reserves, divided by exploratory and development footage drilled (finding rate),
x_t = incremental drilling effort (annual drilling rate); and
λ_t = the proportion of drilling effort that is successful in finding new reserves.

The theoretical specification of the drilling effectiveness function is based upon the assumption that the larger deposits in a mature petroleum basin are discovered first, and that cumulative new reserves, in such mature basins, tend to decline non-linearly as cumulative drilling increases. A plausible functional specification of this non-linear process is

$$Y_t = \psi\, e^{\alpha_1 T}[1 - e^{\alpha_2 X_t}] \tag{2}$$

where
ψ and α_K (k =1, 2) are constant parameters;
T = a proxy variable for technical progress;
ψ = ultimate discoverable reserves (i.e. cumulative new reserves as t becomes large); and
X_t = cumulative drilling effort at the beginning of time t.

By differentiating equation (2) with respect to X, we obtain a simple mathematical specification of drilling effectiveness equation in the following estimable form (Porter, 1992 and Walls, 1994):

$$y_t = \alpha_0 e^{\alpha_1 T} e^{\alpha_2 X_t} \qquad (3)$$

where:

α_0 ,α_1, and α_2 are constant parameters to be estimated.
α_1 = a measure of increases in drilling effectiveness due to changes in technical progress
α_2 = a measure of the responsiveness of the effectiveness of drilling at adding new reserves to changes in cumulative effort--a proxy for the maturity of the geologic basin.
y = drilling effectiveness, the ratio of recoverable hydrocarbon reserve additions and the corresponding incremental footage of successful hydrocarbon wells drilled.

The functional form of drilling equation may be derived by solving the producers' investment decision problem of choosing, simultaneously, the optimal time-paths of both drilling and production activities to maximize the present value of expected net benefits, subject to the following constraints:

(1) Expected new reserve additions decline as drilling effort and cumulative new reserves increase over time. In other words, the rate of change of cumulative new reserves depends on both the cumulative amount of effort expended and cumulative new reserves from past efforts.

(2) Production from new reserves declines exponentially in accordance with the basic petroleum engineering principle, the constant-decline production mechanism.

(3) The rate of change of the stock of proved reserves must be equal, at all time t, to gross new reserves minus current rate of output.

The general solution to the above decision problem is quite complex. However, from the body of the of literature[1] on this subject, we may specify that drilling demand will vary with net economic value of reserve additions and the cumulative drilling effort--a proxy variable for the maturity of the geological region. Specifically, more effort will be put into the search for and development of hydrocarbon reserves if the discounted net benefit per discovery increases. More knowledge about the region--or increased maturity of the geologic region--may or may not lead to more drilling, depending on the nature and quality of the geological information available from past drilling activity.

[1] See Porter (1992), Deacon et al. (1990), Iledare (1990) and Walls (1994).

An estimable drilling demand function can be specified as

$$x_t = \beta_0 \pi_t^{\beta_1} X_t^{\beta_2} \tag{4}$$

where:

β_0, β_1, and β_2 are constant parameters
π_t = net economic value of new reserve additions from incremental drilling effort
X_t = cumulative drilling effort
β_1 = percent change in drilling footage given a percent change in expected net economic value of new reserves
β_2 = a measure of the effect of resource depletion on drilling effort.

4.3 - Model Specification

The theoretical model equations (3) and (4) describe the relationships to be estimated and used to evaluate the supply response of hydrocarbon reserve additions to economic incentives, taxation policy and resource depletion factors. The identity relationship in equation (1) defines gross hydrocarbon reserve additions as the product of drilling effectiveness and drilling effort.

Equation (3) describes drilling effectiveness (y) as a function of cumulative drilling footage (X)--a proxy variable for the maturity of the Gulf of Mexico--and a technical progress variable (T). A log linear specification of equation (3) for statistical and empirical analysis takes the form:

$$\ln y_{it} = \alpha_{0i} D_i + \alpha_{1i} T_{it} + \alpha_{2i} X_{it} + \varepsilon_{it} \tag{5}$$

for i = 1, 2...I (firms) and t = 1, 2...N (time periods), and where ε = the random error term and D represents a firm-size dummy variable.

Equation (4) relates drilling effort (x) to the expected net economic value of new reserves (π) and cumulative drilling effort (X). Cumulative drilling effort is a proxy variable capturing the effects of the maturity of the Gulf OCS on drilling. To facilitate hypotheses testing about the effects of changes in economic and taxation policy variables on drilling behavior among firms of different sizes, we assumed that the expected net economic value of new reserves is some function of the discounted present value of expected future tax rate (z) and expected pre-tax net cash flow per BOE (v). Thus, drilling behavioral equation is approximated with the following log-linear equation (6) for i= 1, 2, 3 (firms) and t= 1, 2, ...N (time periods), and μ represents the random error term.

$$\ln x_{it} = \beta_{0i}D_i + \beta_{1i}\ln X_{it} + \beta_{2i}\ln z_{it} + \beta_{3i}\ln v_{it} + \mu_{it} \tag{6}$$

4.4 - Model Estimation

The databases we developed to estimate the equations (5) and (6) contain pooled observations over the period 1978-1992 for the Gulf of Mexico OCS region. Three categories of firms were used--majors, large and smaller independents--to form the cross-section. Data sources and description of model variables are summarized in Table 4. Given the panel nature of the database developed, equations (5) and (6) cannot be estimated unless a variety of restrictive assumptions regarding the disturbance terms and regression coefficients are invoked. Such restrictions form the basis of the special pooling techniques and procedures discussed extensively in Pindyck and Rubinfeld (1991), Madalla (1977) and Gujarati (1988).

4.4.1 - Empirical Results and Analysis: Pooled ordinary least squares (OLS) estimates of equation (5) using the covariance pooling technique (CAT)[2] are presented in Table 5 for the Gulf of Mexico OCS region. Column A in Table 5 represents OLS estimates of an unrestricted version of the log-linear approximation of equation (3), which is equivalent to estimating a separate equation for each firm.

The empirical equation presented in column (A) of Table 5 which describes the effectiveness of drilling in adding new reserves in the Gulf of Mexico OCS region has satisfactory descriptive statistics. More than 75 percent of the variation in the effectiveness of drilling at adding new reserves is explained by the equation. The coefficients of firm-size/resource-depletion interaction in the find-rate equation have the expected signs, and are statistically significant. The standard error of the regression is less than three percent of the mean of the dependent variable.

Several hypotheses were performed on the regression results including a F-test for homogeneity of the regression--a common intercept and common slope test:

$$H_0 : \alpha_1 = \alpha_{11} = \alpha_{12} = \alpha_{13}; \alpha_2 = \alpha_{21} = \alpha_{22} = \alpha_{23}; \alpha_1 = \alpha_{11} = \alpha_{12} = \alpha_{13}$$

There is enough statistical evidence to reject the null hypothesis of homogeneity in the regression equation. The intercept dummies are statistically significant and are different for firms of different sizes.

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[2]The covariance analysis technique (CAT) is the oldest method of allowing for cross-sectional differences or intertemporal differences when pooling cross-section time series data. The restrictive assumptions underlying this procedure for pooling are 1) some of the slope coefficients are equal and stochastic and 2) the intercepts are different (at least for one of the individual cross-section) and stochastic. Usually the CAT estimator is unbiased and consistent, but it may be inefficient if the error term is correlated over time and/or over the cross section. See Madalla (1977), Gujarati (1988) and Pindyck and Rubinfeld (1991) for discussions of pooling techniques and procedures.

Table 4. Descriptions of Model Variables and Data Sources

x	Total exploratory and development footage drilled (000 Ft.). Source: Computed for firms of different sizes from MMS Borehole data file.
X	Proxy variable for resource depletion. Measured as previous year-end cumulative total footage drilled (Million Ft.). The series is calculated as the sum of past years' total footage drilled since 1978.
y	Drilling effectiveness (find rate), BOE/FT (1 Mcf = 0.18 BOE). Calculated as the three-year moving average of recoverable-hydrocarbon-reserve-additions per foot of successful wells completed lagged one year.
v	Pre-tax cash flow, $/BOE. The series is calculated for firms of different sizes from several issues of the Arthur Anderson's survey of reserve disclosure. We measured "v" as the discounted future pre-tax net cash flows of recoverable reserves. The series is deflated using the PPI (1982=100).
z	Proxy variable for cash flow reduction to operators, $/Mcf. The series is calculated as the difference between discounted pre-tax net cash flows and discounted post-tax net cash flows. The series is deflated using PPI (1982=100).
T	Percent of total drilling effort that successfully adds new reserves--a proxy variable for technical progress. Measured as a three-year moving average of successful drilling footage divided by a three-year moving average of total drilling footage.
D_1	Dummy variable (intercept) for major operators on the Gulf OCS.
D_2	Dummy variable (intercept) for large independent operators.
D_3	Dummy variable (intercept) for smaller independent operators.

Table 5. Estimated Mode Equations for Drilling and Drilling Effectiveness [a]

Parameters	Drilling Effectiveness (A) = ln y	Drilling Effort (B) = ln x
D_1	7.246	32.681
	(8.468)	(4.209)
D_2	5.403	21.526
	(4.844)	(3.455)
D_3	7.016	28.042
	(27.12)	(3.619)
D_1X	-0.015	
	(4.152)	
D_2X	-0.040	
	(3.595)	
D_3X	-0.078	
	(2.832)	
D_1 ln X		-2.171
		(3.377)
D_2 ln X		-1.271
		(2.269)
D_3 ln X		-2.221
		(3.010)
D_1T	-2.199	
	(1.322)	
D_2T	1.991	
	(0.769)	
D_3T	-1.868	
	(1.488)	
D_1 ln z		-0.856
		(1.737)
D_1 ln z		-1.620
		(2.958)
D_1 ln z		-1.333
		(2.146)
ln v		0.417
		(1.750)
Descriptive Statistics:		
Degrees of Freedom	21	17
Adjusted R^2	0.762	0.925
S.E.R	0.156	0.222
Error of the Mean	0.028	0.032

[a]The absolute t values are in parentheses below the regression coefficients.

The negative and significant coefficients of cumulative drilling footage--a proxy variable for resource depletion facing each firm size--provide a strong statistical evidence of diminishing returns in drilling outcomes as drilling progresses. A Wald test of coefficient restrictions indicates statistically identical (99 percent confidence) effects of resource depletion on the hydrocarbon finding rate for large independents and smaller independents. But the test indicates that the effects of resource depletion on find rate for all independents and the majors are not statistically identical. The majors are more negatively affected by resource depletion in their search for petroleum in mature petroleum basins like the Gulf of Mexico than are the independents.

Statistical tests on the individual coefficients of the total success ratio--the proxy for technical progress--show the three coefficients to be insignificant at the 5 percent level. However, a Wald test of coefficient restrictions on equation (5) shows some statistical evidence to reject the null hypothesis:

$$H_0: \alpha_{11} = \alpha_{12} = \alpha_{13} = 0$$

That is, there is some statistical evidence to suggest that changes in technology affects the find rate of new reserves among firms of different sizes operating on the Gulf of Mexico OCS. In addition, the test also shows we cannot reject the null hypothesis of equality in the coefficients of technical progress among firms of different sizes. Thus, there is no statistical evidence that the effect of the aggregate success ratio on the hydrocarbon find rate differs among firms of different sizes operating on the Gulf OCS.

The second column in Table 5 presents estimates of a restricted version of equation (6) which relates firms' drilling effort to economic incentives--pre-tax net cash flow, effective tax rate and resource depletion. The restricted OLS estimates of equation (6) reported in column B of Table 5 show good statistical properties. The adjusted R^2 is 0.922. The standard error of regression, 0.227, represents 3 percent of the mean of the dependent variable. All the estimated coefficients have the expected signs, and are statistically significant at a 5 percent level, with the exception of the coefficient of the pre-tax cash flow which is only significant at the 10 percent level.

Several hypotheses were tested using the unrestricted OLS estimates of equation (6). The null hypothesis of common slopes and common intercept at the 5 percent level of significance is rejected. There is strong evidence to reject homogeneity of the regression using the F-test. A Wald test of coefficient restrictions on the estimated equation shows no statistical evidence, at 95 percent confidence level, to reject the null hypothesis:

$$H_0: \beta_{31} = \beta_{32} = \beta_{33} = \beta_3$$

Thus, the test results suggest some statistical evidence that drilling responsiveness to pre-tax cash flows may be the same for firm of different sizes. The test also shows a dissimilarity in the responsiveness of drilling effort to the average tax rate among firms of different sizes in the 1980s.

The large independent firms on average have a more negatively elastic drilling response to average effective tax rate than the majors which have a negative inelastic drilling response to taxes and the smaller independents. It is noted, however, that the drilling response to economic incentives among firms of different sizes is only marginally significant at the 10 percent level in the Gulf OCS region according to our empirical results. The empirical results further suggest a rather striking difference in the negative response of drilling to resource depletion among the majors and large independents than the statistical difference observed between the smaller independents and the majors. In general, however, drilling responsiveness among firms of different sizes is negatively elastic to recoverable resource depletion.

4.4.2 - Economic Interpretation of the Empirical Results: The relative importance of the effects of economic incentives, taxation policy and resource depletion on drilling effort by firms of different sizes operating on the Gulf OCS can be compared using the concept of elasticity. Elasticity, by definition, is simply a measure of the effect of a percent change in one explanatory variable on a dependent variable, *ceteris paribus*. Table 6 presents empirical estimates of the elasticity of drilling and find rate with respect to economic incentives, taxes and depletion in the Gulf of Mexico OCS region.

In general, if a variable Y is log-linearly related to an independent variable X such that: $\ln Y = a + c \ln X$. then, the elasticity of Y with respect to X equals c. Thus, the coefficients of the three drilling regression results presented in Column B of Table 6 provide a direct measure of drilling elasticity for firms of different sizes operating on the Gulf OCS. The large independent firms on average has a more negatively elastic drilling response to average effective tax rate than the majors which has a negative inelastic drilling responsiveness to taxes and the smaller independents with a negative elastic drilling response to taxes on the Gulf OCS. Estimates of drilling elasticity with respect to economic incentives among firms of different sizes were found to be statistically identical, whereas Table 6 shows a statistically significant drilling elastic response to depletion for firms of different sizes in the Gulf region.

The estimated responsiveness of find-rate to the growing maturity of the Gulf of Mexico in Table 6 is derived as the product of the coefficient of the majors' cumulative drilling effort in the estimated find-rate regression times the current cumulative effort for the period. In other words, if a variable Y is related to another variable X such that $Y = \alpha e^{\beta X}$, then the elasticity of Y with respect to X equals $\beta * X$.

As shown in Table 6, the effectiveness of the majors in adding more new reserves per drilling effort seem to be more negatively affected with cumulative drilling than it is for either the large or smaller independents. The majors' effectiveness in adding new reserves is significantly elastic with respect to cumulative drilling--a proxy for basin maturity, whereas the large and smaller independents' effectiveness is significantly inelastic in the Gulf OCS.

Table 6. Estimated Elasticity of Drilling Effort and Drilling Effectiveness

Firm Type/ Exogenous Variable	Drilling Effectiveness	Drilling Effort
MAJORS:		
Economic Incentives	n/a	0.417
Effective Tax Rate	n/a	-0.856
Depletion	-1.117	-0.457
LARGE FIRMS:		
Economic Incentives	n/a	0.417
Effective Tax Rate	n/a	-1.620
Depletion	-0.985	-1.271
SMALLER FIRMS:		
Economic Incentives	n/a	0.417
Effective Tax Rate	n/a	-1.333
Depletion	-0.794	-2.974

5. SUMMARY AND CONCLUSIONS

The primary objective of this project is to discern and quantify any differences in the performance of firms of different sizes (majors, large and smaller independents) in their search for and development of petroleum resources on the Gulf of Mexico OCS. The motivation for the project is to evaluate the widespread apprehension that if the independents were to play a larger role in the search for and development of hydrocarbon resources on the OCS, resources would be less aggressively and less efficiently developed.

The simple descriptive statistics of upstream oil and gas industry indicators we developed indicate that independents have been both more aggressive and successful than the majors in exploration, while the majors have been moderately more successful than independents in development drilling on the OCS. In the aggregate, both the large and smaller independents have been at least marginally more effective than the majors in adding hydrocarbon reserves per successful foot drilled.

On average, for every foot of successful well drilled by the majors on the OCS 227 barrels of oil equivalent (BOE) of new hydrocarbon reserves were added to original recoverable hydrocarbons in place during the period 1983-1992. Whereas the large independents added 242 BOE while smaller independents added 312 BOE of hydrocarbons for every foot of successful wells drilled during the same period. If drilling effectiveness were calculated using total footage drilled in the denominator rather than successful footage drilled, the difference narrows. Majors added 106 BOE per foot drilled while large independents added 104 BOE per foot and smaller independents 125 BOE per foot drilled.

To investigate these differences more carefully, we developed a hydrocarbon model of reserve additions on the Gulf of Mexico OCS. The hydrocarbon model views drilling as the primary means of generating new reserve additions, subject to resource availability, economic and policy incentives, cumulative geological knowledge, and technical progress. The model is estimated using pooled, cross-section (majors, large and smaller independents) and time series data (for the period 1978 through 1992).

Empirical estimates of the hydrocarbon model confirm the inferences drawn from descriptive analysis of MMS data on drilling effort and outcomes and do not support the expectation that hydrocarbon resources in the Gulf OCS would be developed less aggressively or less efficiently if independents were to play a progressively larger role. Our results provide no statistical evidence to suggest any differences among firms of different sizes in the effect of technical progress--measured by movements in aggregate success ratio--on the gross find-rate on new hydrocarbon reserves on the Gulf OCS.

Moreover, there is no statistical evidence of any significant difference in the responsiveness of the gross find-rate of new reserves to technical progress for majors and independents in their search for hydrocarbon. But the growing maturity of the Gulf of Mexico OCS) affects more negatively the majors' effectiveness in adding new reserves than it affects the large and smaller independents.

According to our empirical results, there is no statistical difference among firms of different sizes in the responsiveness of drilling effort on the OCS to pre-tax net cash flow (economic incentives). However, the OLS estimates of the hydrocarbon drilling equation suggest a negatively elastic response of drilling to higher effective tax rates among the independents and an inelastic drilling response to taxes among the majors. There is a strong evidence in the empirical results to support expectations of a positively inelastic response of drilling effort to an increase in economic incentives. In addition, the results show that drilling response to resource depletion is more negatively elastic for the majors than it is for the independents.

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Appendix A. List of OCS Operators Included in the Report

MMS Code	Operator Name	Classification
1	Conoco Inc.	Major
2	Atlantic Richfield Company	Major
3	Union Oil Company of California	Major
5	Four Star Oil & Gas Company	Small
8	Ocean Drilling & Exploration Company	Large
12	Freeport Minerals Company	Large
23	Homestake Sulphur Company	Small
35	Kerr-McGee Corporation	Large
39	Mobil Oil Corporation	Major
40	Texaco Inc.	Major
47	The Superior Oil Company	Major
48	Forest Oil Corporation	Small
56	Phillips Petroleum Company	Major
59	Amerada Hess Corporation	Major
64	Hunt Oil Company	Large
66	Placid Oil Company	Small
70	CSX Oil & Gas Corporation	Small
71	Pennzoil Producing Company	Major
73	General American Oil Company of Texas	Small
78	Chevron U.S.A. Inc.	Major
81	Tenneco Oil Company	Major
83	The Louisiana Land and Exploration Company	Large
105	Apache Corporation	Large
112	Gulf Oil Corporation	Major
114	Amoco Production Company	Major
115	Marathon Petroleum Company	Major
117	Shell Oil Company	Major
128	Elf Aquitaine, Inc.	Large
131	Southland Royalty Company	Small
134	General Crude Oil Company	Small
144	Diamond Chemicals Company	Large
148	Union Pacific Resources Company	Large
161	Hamilton Brothers Oil Company	Small
162	Agip Petroleum Co. Inc.	Large
167	Pennzoil Company	Major
170	Anadarko Production Company	Large
185	Samedan Oil Corporation	Large
222	Columbia Gas Development Corporation	Large
227	Belco Petroleum Corporation	Small

Appendix A (contd.)

231	Pogo Producing Company	Small
232	Odeco Oil & Gas Company	Large
233	Mesa Petroleum Co.	Large
236	SONAT Exploration Company	Large
240	ANR Production Company	Large
245	C & K Offshore Company	Small
250	ORYX ENERGY COMPANY	Large
274	Transco Exploration Company	Large
276	Exxon Corporation	Major
278	Texas Pacific Oil Company, Inc.	Small
282	CNG Producing Company	Large
295	Koch Industries, Inc.	Large
298	Quintana Offshore, Inc.	Small
333	Enron Corp.	Large
334	Houston Oil & Minerals Corporation	Small
346	Oxy Petroleum, Inc.	Major
353	Eason Oil Company	Small
362	BHP Petroleum (Americas) Inc.	Large
369	CanadianOxy Offshore Production Co.	Large
376	Pelto Oil Company	Small
403	Challenger Minerals Inc.	Large
407	Santa Fe Minerals, Inc.	Small
415	Energy Development Corporation	Large
418	Aminoil Inc.	Small
420	Rutherford Oil Corporation	Small
428	McMoRan Oil & Gas Co.	Large
457	Ashland Exploration, Inc.	Large
464	Zapata Exploration Company	Large
477	McMoRan Offshore Production Co.	Large
479	Natomas Offshore Exploration, Inc.	Small
481	Petrofina Delaware, Incorporated	Large
491	Coastal Oil & Gas Corporation	Large
538	Corpus Christi Oil and Gas Company	Small
539	MidCon Exploration Company - Gulf Coast	Small
540	MOBIL OIL EXPLORATION & PRODUCING SOUTHEAST INC.	Major
560	Seneca Resources Corporation	Large
565	Mobil Producing Texas & New Mexico Inc.	Major
582	PG&E Resources Offshore Company	Large
583	BelNorth Petroleum Corporation	Small
593	BP Exploration Inc.	Major
623	MTS Limited Partnership	Small
641	Tomlinson Offshore, Inc.	Small

644	C & K Offshore Company	Small
655	Ranger Oil Company	Small
659	Mark Producing, Inc.	Small
672	Seagull Energy E&P Inc.	Large
677	Howell Petroleum Corporation	Small
683	Union Texas International Corporation	Large
687	CXY Energy Inc.	Large
689	Shell Offshore Inc.	Major
722	Koch Exploration Company	Large
724	Marathon Oil Company	Major
730	Walter Oil & Gas Corporation	Small
748	DelMar Operating, Inc.	Small
762	Genesis Petroleum Corporation	Small
768	BHP Petroleum Company Inc.	Large
771	Texaco Exploration and Production Inc.	Major
774	Taylor Energy Company	Small
777	OXY USA Inc.	Major
780	Quintana Petroleum Corporation	Small
784	Santa Fe International Corporation	Large
788	Phillips Oil Company	Major
800	TXP Operating Company	Large
803	Hunt Petroleum Corporation	Large
805	Rosewood Resources, Inc.	Small
818	Hardy Oil & Gas USA Inc.	Small
822	Maxus Exploration Company	Large
828	Cockrell Oil Corporation	Small
846	Hall-Houston Oil Company	Small
888	KIRBY EXPLORATION COMPANY OF TEXAS	Small
898	TOTAL MINATOME CORPORATION	Small
915	Mitchell Energy Corporation	Large
926	LLOXY Holdings, Inc.	Small
962	EP Operating Limited Partnership	Small
963	FMP Operating Company, a Limited Partnership	Large
967	Atlantic Richfield Company	Major
968	Union Texas Petroleum Corporation	Large
981	Anadarko Petroleum Corporation	Large
985	Union Exploration Partners, Ltd.	Major
986	Japex (U.S.) Corp.	Large
992	Diamond Shamrock Offshore Partners Limited Partnership	Large
1001	IP Petroleum Company, Inc.	Small
1006	Hughes-Denny Offshore Exploration, Inc.	Small
1022	Sun Operating Limited Partnership	Large

1023	Adobe Resources Corporation	Large
1026	Mesa Operating Limited Partnership	Large
1029	TXO Production Corp.	Small
1035	Santa Fe Energy Operating Partners, L.P.	Large
1046	Brooklyn Union Exploration Company, Inc.	Large
1055	Mobil Exploration and Producing North America Inc.	Major
1071	Conn Energy, Inc.	Small
1072	Cliffs Oil and Gas Company	Small
1082	Freeport-McMoRan Resources Partners, Limited Partnership	Large
1089	Norcen Explorer, Inc.	Small
1091	Gulfstream Resources, Inc.	Small
1099	Torch Operating Company	Small
1102	Century Offshore Management Corporation	Small
1103	Enron Oil & Gas Company	Large
1104	Wintershall Corporation	Small
1108	Sandefer Offshore Operating Co.	Small
1112	Ampolex (Texas), Inc.	Small
1116	Conquest Exploration Company	Small
1123	Raintree Resources, Inc.	Small
1131	American Exploration Company	Small
1138	Zilkha Energy Company	Small
1139	King Ranch Oil and Gas, Inc.	Small
1143	Offshore Development Interests Inc.	Small
1151	NCX Company, Inc.	Small
1154	Partners Oil Company	Small
1158	Gas Transportation Corp.	Small
1160	Nippon Oil Exploration Offshore U.S., Ltd.	Large
1173	Wolverine Exploration Company	Small
1185	Aviva America, Inc.	Small
1187	Great Western Offshore Inc.	Small
1194	Pel-Tex Oil Company	Small
1207	Petrobras America Inc.	Large
1210	Wacker Oil Inc.	Small
1211	Aquila Energy Corporation	Small
1217	AEDC (USA) INC.	Small
1225	Wayman W. Buchanan, Inc.	Small
1226	The Stone Petroleum Corporation	Small
1241	Washington Energy Exploration, Inc.	Small
1245	Hughes Eastern Petroleum, Inc.	Small
1246	Senior - G & A Operating Company, Inc.	Small
1247	Aran Energy Corporation	Small
1254	Pilgrim Exploration Corp.	Small

1257	Neomar Resources, Inc.	Small
1259	First Energy Corporation	Large
1279	Gulfstar Operating Company	Small
1283	Offshore Energy Development Corporation	Small
1284	W & T Offshore, Inc.	Small
1291	Pennzoil Exploration and Production Company	Major
1295	Falcon Offshore Operating Company	Small
1316	Flash Gas & Oil Southwest, Inc.	Small
1324	B T Operating Co.	Small
1334	NERCO Oil & Gas, Inc.	Large
1344	Seastar Energy Corporation	Small
1351	General Atlantic Resources, Inc.	Small
1364	Newfield Exploration Company	Small
1370	TransTex Resources, Inc.	Small
1374	Transco Exploration and Production Company	Large
1376	Linder Oil Company, A Partnership	Small
1379	Brock Minerals Corporation	Small
1385	Chieftain International (U.S.) Inc.	Large
1405	Pogo Gulf Coast, Ltd.	Small
1407	Tatham Offshore, Inc.	Small
1444	Torch Oil & Gas Company	Small
1482	Nippon Oil Exploration U.S.A. Limited	Large
1489	BG Exploration America, Inc.	Small
1500	Elf Exploration, Inc.	Large
1509	Global Marine Oil & Gas Company	Large
1512	Aquila Energy Resources Corporation	Small
1523	Levinson Partners Corporation	Small
1531	Freeport-McMoRan Oil & Gas Company	Large
1548	Tana Oil and Gas Corporation	Small
1550	Unocal Exploration Corporation	Major
1551	Santa Fe Energy Resources, Inc.	Large
1570	Greenhill Petroleum Corporation	Small
1578	British-Borneo Exploration, Inc.	Large
1586	Petsec Energy Inc.	Small
1597	Freeport-McMoRan Inc.	Large
1601	Gulfstar Energy, Inc.	Small
1605	SEKCO Energy, Inc.	Small
1624	Trade & Development Corporation	Small
1626	Pan Petroleum Master Limited Partnership	Small
1643	UMC Petroleum Corporation	Small
1663	Ivory Production Co	Small
1673	SCANA Petroleum Resources, Inc.	Small

Appendix A (contd.)

1674	Louis Dreyfus Reserves Corp.	Small
1680	BP Exploration & Oil Inc.	Major
1687	Matrix Oil & Gas, Inc.	Small
1689	Murphy Exploration & Production Company	Large
1701	Midcon Offshore, Inc.	Small
1728	Shell Frontier Oil & Gas Inc.	Major
1750	Pennzoil Petroleum Company	Major
1758	Offshore Production & Salvage, Inc.	Small
1759	Forcenergy Gas Exploration, Inc.	Small
1764	Energy Resource Technology, Inc.	Small
1767	OEDC Exploration & Production, L.P.	Small
1777	Flores & Rucks, Inc.	Small
1787	Entre Energy Corporation	Small
1815	Santa Fe Minerals, Inc.	Small
1818	Ashlawn Energy, Inc.	Small
1819	ATP Oil & Gas Corporation	Small
1832	Forcenergy Gas Exploration, Inc.	Small
1855	Vastar Resources, Inc.	Large

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.