PROPERTIES OF ACCOUNTING NUMBERS UNDER VARIOUS DEFINITIONS OF COST CENTERS IN THE PETROLEUM EXPLORATION INDUSTRY

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I. Introduction

Current accounting practices with regard to the selection of cost centers to accumulate exploration costs for the purpose of matching them with revenues vary considerably within the petroleum exploration industry. Various bases used for the selection of a cost center are (1) geographic regions, (2) political units, (3) legal or property acquisition units, (4) organizational units, (5) area of interest, and (6) geologic areas. Treatment of the entire firm as a single cost center lies at one end of the spectrum of available choices; treatment of each lease as a separate cost center lies at the other.

The cost center decision, in essence, involves the determination of the number and size of cost centers into which a firm's operations are divided up for the purpose of matching expense and revenues. This paper presents a model to analyze the effect of the size of cost centers on the properties of several accounting numbers, such as earnings, cash flows, capitalized value of exploration costs and rate of return on owners' equity and their interrelationships.

Several points of view found in the accounting literature on the issue of cost center selection in the petroleum exploration industry are briefly reviewed in the remainder of this section. Analytical models of the effect of cost center decision on several accounting variables for steady state and changing firms are presented in Sections II and III, respectively. Summary and conclusions are contained in Section IV.

Each of the bases for selection of a cost center mentioned earlier is desirable in some respects and undesirable in others. These bases may be visualized as points in a multi-dimensional space of attributes. For example, cost centers based on geographic regions can be unambiguously defined in terms of readily identifiable surface features of the earth. Relative precision and lack of arbitrariness of this basis, however, are accompanied by its irrelevance to the existence and distribution of hydrocarbons beneath the surface. Within the same broadly defined geographic region, very different subsurface conditions may exist and the economies of discovery and exploitation of various pools of oil and gas may be quite different. Unlike geographic regions, geologic regions are defined in terms of subsurface characteristics of the earth's crust which are directly relevant to the existence and exploitability of hydrocarbon deposits. Geologic regions, however, lack the precision of definition associated with the geographic regions. Geologic regions can be defined at varying levels of aggregation from large geologic areas such as provinces, basins and trends, through subbasins and fields of hydrocarbon deposits to individual pools. The boundaries of geologically defined cost centers become increasingly precise as the size of the cost center becomes smaller.

Organizationally defined cost centers represent an attempt to recognize that the hydrocarbon reserves discovered within an administrative unit are the results of all the exploration costs incurred. Since the probability of discovery of reserves is low, organization-wide cost centers even out the product cost, which would otherwise be subject to substantial variations by mere chance. While they iron out the effects of uncertainty on product cost, the organization-wide cost centers also do not distinguish between the geologic and geographic areas where the cost of discovery and production is indeed quite different due to differences in accessibility and the quality of hydrocarbon deposits.

Cost centers defined on the basis of political units recognize the intercountry differences in the economic and political environment. Though political units are, like organizational units, unambiguously defined, they might straddle over or be straddled by units defined by other criteria. Depending on the size of the country and the incidence of hydrocarbon deposits in it, a political unit may be administratively too small to be treated as a single cost center.

The lease or property acquisition unit as a cost center has been widely used in the industry. Often, this basis is justified because the records required for such practice conform to the requirements of the tax law. Since the same deposit or field of deposits may be divided into a number of acquisition units, the product costs from different units are often quite different, depending on the drilling results from each tract.

Another widely discussed basis of defining cost centers is the "area of interest" as defined by the firm. The argument goes that the petroleum exploration firms plan and control their activities by defining various areas in which they are interested. Such areas are usually placed under a separate administrative unit and therefore represent a proper basis for defining cost centers.

The area of interest definition is quite flexible because an area of interest is what the management defines it to be. While such flexibility makes it more suitable for the management, it appears less objective than externally defined concepts of cost center such as political units, geographic or geologic regions and fields, etc. From the point of view of managerial control it is clearly a superior policy to allow the management a free hand in defining the cost center--as is accomplished by the area of interest definition. However, from the point of view of external users of accounting information, such flexibility leads to the problem of intercompany incomparability of accounting numbers.

Each basis of defining cost centers has its own advocates in the accounting literature. For example, Coutts has argued strongly in favor of adopting the area of interest as the cost center for accumulating costs.[1] According to him the management actually plans its operations on the basis of area of interest, and therefore such a definition of cost center is not only convenient from the point of view of compatibility of the accounting system with the organization but it also provides the cost information most useful to the management.

Robert Fields, on the other hand, argues for treating an individual reservoir of hydrocarbons as the appropriate cost center.[2] In specific cases, he advocates including a field of reservoirs within a simple cost center depending on whether the individual reservoir or the field constitute the unit to which most expenditures are identifiably directed. He rejects the use of cost centers based on acquisition units (leases, etc.) on the grounds that such a definition results in different unit costs of production under essentially identical economic circumstances. Fields' elaborate argument against the treatment of a lease as the cost center is somewhat contradictory because when his recommendation on cost centers is combined with his recommendations[3] for expensing all prospecting, indirect acquisition and unsuccessful exploration costs and most prediscovery carrying costs, the results obtained from lease-based and field-based cost centers are not too different. Thus, while arguing in favor of field-based cost centers, Fields has, in effect, recommended lease-based cost centers.

Arthur Andersen and Company[4] favor the use of country-by-country cost centers for all countries with the exception of U.S. and Canada which, it recommends, might be combined into a single cost center. For the firms whose operations are limited to the North American continent, this would imply a single company-wide cost center.

The Accounting Principles Board established a committee to study the accounting and reporting practices in the extractive industries to determine appropriate practices and to narrow the accounting differences in the industry. The determination of the cost center was the first of five topics to which the first phase of the Committee's considerations were directed. After a consideration of various arguments, the Committee reached a tentative conclusion in favor of using geological areas at the field level as the basis of defining cost centers.[5] The Committee's position is identical to the position advocated by Fields in Accounting Research Study No. 11.

From a brief review of the cost center controversy, it would appear that the essence of the matter is not the basis of cost center definition *per se* but the number and size of cost centers that a firm is divided into on the basis of each definition. The cost center decision is important only for the purpose of external reporting. For managerial information and control, it is always possible to provide data aggregated according to any given criterion since the basic records have to be maintained on a greatly disaggregated level for the purpose of tax accounting. For external reporting, however, only one basis of aggregation is used. The effects of the cost center basis on externally reported accounting numbers arise primarily because each basis usually results in a different number of cost centers of varying sizes within the firm. In this study, the problem of selecting specific cost center bases is abstracted by analyzing the effects of cost center size and number on the properties of several externally reported accounting numbers. Models of behavior of accounting numbers such as cash flow, reported earnings and return on assets for steady state firms are developed in the next section.

II. Steady State Firm

Consider a firm whose petroleum exploration activities have reached a steady state level; that is, it has been exploring for petroleum at a constant rate in an unchanging environment for a sufficiently long period of time. For such a firm, the average rate of discovery of new reserves is equal to the average rate of depletion of the existing reserves. While various accounting variables fluctuate from period to period, the steady state of the firm implies that these variables are distributed around a mean value which remains unchanged over time. After analyzing the effect of the cost center decision on the steady state firms, the case of new firms is analyzed in the next section.

For any given period t, exploration activities of the firm are divided up into q cost centers of equal size. Each period, the firm drills a total of N exploratory wells of which $n = \frac{N}{q}$ are drilled in each of the q cost centers. The probability of finding a commercial reserve of hydrocarbons in a well is θ and is independent of all other wells. Thus the probability of not finding oil in a given well is $(1 - \theta)$ and the probability of not finding oil in any of the n wells drilled in a given cost center is $(1 - \theta)^n$. Drilling of all wells is completed within the period in which it is started and the success or failure of each well is known by this time.

TABLE I

t, τ	= time subscript.
q	= number of cost centers.
N	= total number of exploration wells drilled per period.
n	$= \frac{N}{q}$ number of exploration wells drilled per period per cost center.
c	= cost of exploration per well.
r	= number of successful cost centers.
X	= net cash flow.
ϵ	= expected value operator.
s_{it}	= number of successful wells in cost center i in period t.
S_t	= number of successful wells in all cost centers in period t.
θ	= probability of a well containing commercial reserves.
ϕ	$= 1 - (1 - \theta)^n$ = the probability of a cost center with n wells having at least one successful well.
x	= net operating cash flow per successful exploratory well per period.
L	= lifetime of a successful exploratory well.
I	= periodic earnings.
R	= rate of return on owners' equity.
$W_{u,v}$	= results of explorations from period u to period v inclusive.
A	= capitalized value of exploration costs.
E	= owners' equity.
D	= cash dividends to shareholders.

Within each cost center, the full cost concept of capitalization is used. If one or more wells in a cost center is successful, all exploration costs of the cost center are capitalized for amortization against subsequent production. If none of the n wells drilled is successful in a given cost center--the probability of such an event is $(1 - \theta)^n$--all exploration costs incurred in the cost center are expensed.

In this model, only two parameters are affected by the cost center decision, the number of cost centers q and the number of wells per cost center, n. Since the total number of holes drilled is fixed at N, q and n have a one-to-one relationship and are not independent of each other. While we use both these parameters in the models presented below, they represent only one and not two dimensions of variation.

Let s_{it} be the number of successful wells in the ith cost center in period t. Since each well has probability θ of being successful, s_{it} is a random variable with binomial distribution and parameters θ and n.

(1) $$s_{it} \sim B(\theta, n) .$$

Let S_t be the total number of successful wells in period t for the entire firm. Since it is equal to $\sum_{i=1}^{q} s_{it}$, S_t is also a binomially distributed random variable with parameters θ and N.

(2) $$S_t \sim B(\theta, N) .$$

Let r_t be the number of cost centers which have at least one successful well drilled in period t. The exploration costs of these r_t cost centers, therefore, are fully capitalized and the costs of the remaining $(q - r_t)$ cost centers are fully expensed in period t. Since the probability of striking all dry holes in a cost center is $(1 - \theta)^n$, r_t itself is a random variable with binomial distribution and parameters $\phi = 1 - (1 - \theta)^n$ and q, respectively

(3) $$r_t \sim B(\phi = (1 - (1 - \theta)^n), q) .$$

Let c be the cost of exploration per well. Therefore, the total cost of exploration each period is $Nc = nqc$, out of which $nc(q - r_t)$ is expensed. Since r_t is a random variable, so are the capitalized and expensed costs of exploration with expected values of $ncq\phi$ and $ncq(1 - \phi)$, respectively.

Let x be the uniform net cash flow per successful well for each of the L periods immediately following the drilling. In other words, if an exploratory well drilled in period t is successful, the operation of the well results in net cash inflow of L dollars in each of the L periods beginning $t + 1$.

Net Cash Flow

For an exploration firm which has reached the steady state, periodic net cash flow is the difference between cash inflow from the operation of successful wells drilled in the previous L periods and the cash outflow to meet the costs of exploration. Thus the net cash flow in period t is

$$(4) \qquad X_t = (x \cdot \sum_{j=1}^{L} S_{t-j}) - Nc .$$

The time series of net cash flow is a moving average quantity. The expectation of cash flow τ periods into the future is

$$(5) \quad \epsilon(X_t/S_{t-L}, \ldots, S_{t-\tau+1}) = \begin{cases} - Nc + x \sum_{i=t-L}^{t-\tau-1} S_i + \epsilon(x \sum_{i=t-\tau}^{t-1} S_i) & \text{for } \tau \leq L \\ - Nc + \epsilon(x \sum_{i=t-L}^{t-1} S_i) & \text{for } \tau > L \end{cases}$$

Since the periodic cost of exploration, Nc, is constant over time, the net cash flow in period t depends on the results of exploration over the previous L periods--from t - L to t - 1. If the interval of prediction τ is greater than L, exploration results for all L periods that will determine the net cash flow in period t are unknown at the time of prediction and therefore the expected value of net cash flow depends entirely on the expected exploration results. If, on the other hand, the interval of prediction τ is less than or equal to L, the exploration results for $(L - \tau)$ periods which affect the cash flow are already known. The expected net cash flow in period t therefore depends on these known results and the expected results for τ periods from $t - \tau$ to $t - 1$. Since the expected value of S_i is $N\Theta$, equation (5) can be rewritten as

$$(6) \quad \epsilon(X_t/S_{t-L}, \ldots, S_{t-\tau+1}) = \begin{cases} - Nc + x \sum_{i=t-L}^{t-\tau-1} S_i + x\tau N\Theta & \text{for } \tau \leq L \\ - Nc + xLN\Theta & \text{for } \tau > L \end{cases}$$

Similarly, the variance of cash flow τ periods into the future is

$$(7) \quad Var(X_t/S_{t-L}, \ldots, S_{t-\tau+1}) = \begin{cases} x^2 \tau N \theta(1 - \theta) & \text{for } \tau \leq 1 \\ x^2 LN\theta(1 - \theta) & \text{for } \tau \geq L \end{cases}$$

The net cash flow series is serially correlated with correlation coefficient, ρ, a function of L

$$(8) \qquad \rho_{X_t, X_{t-1}} = 1 - 1/L$$

which implies that the longer the time span over which proved reserves are exploited, the higher is the serial correlation between successive cash flows. Lengthening the time span of exploitation reduces the variability associated with periodic cash flows.

The properties of the cash flow series discussed here are independent of the cost center decision because this decision does not affect the timing or amount of cash flow in any way. However, in what follows, expressions are developed for other accounting variables which are affected by the cost center decision from the basic framework and definitions specified above.[6]

Earnings

Periodic earnings of a steady state firm with q cost centers in each period is the difference between net revenue from production and the matched expenses. Since each successful exploration well yields net production revenue of x dollars per period for L periods, the total net revenue for all wells in period t is

$$x \sum_{i=t-L}^{t-1} S_i \,.$$

Expenses of period t arise from two sources: (1) amortization of capitalized exploration costs during the past periods and (2) recognizing the current period cost of exploration in those cost centers which are completely dry. Since r_t is the number of successful cost centers in period t, the latter amount is $cn(q - r_t)$. If it is assumed that the capitalized exploration costs of successful cost centers are amortized at a uniform rate over L periods, the amortization charge in period t is

$$\frac{nc}{L} \sum_{i=t-L}^{t-1} r_i \,.$$

Therefore, the earnings of the firm for period t can be written as

$$I_t = x \sum_{i=t-L}^{t-1} S_i - \frac{nc}{L} \sum_{i=t-L}^{t-1} r_i - nc(q - r_t) \,. \tag{9}$$

Note that both S_i and r_i are random variables, and, therefore, even if the exploration program is known in advance, the income in period t is a random variable dependent on the results of exploration in the preceding L periods. The expectation of earnings τ periods into the future is

$$\epsilon(I_t/W_{t-L,t-\tau-1}) = \begin{cases} x \sum\limits_{t-L}^{t-\tau-1} S_i + x\tau N\Theta - \frac{nc}{L} \sum\limits_{i=t-L}^{t-\tau-1} r_i - \frac{Nc}{L}\tau\phi - Ncq(1-\phi) & \text{for } \tau \leq L \\ xLN\Theta - Nc & \text{for } \tau \geq L \end{cases} \tag{10}$$

where $W_{t-L,t-\tau-1}$ represents the results of exploration from period $t - L$ to $t - \tau - 1$ inclusive and $\phi = \{1 - (1 - \Theta)^n\}$. For prediction beyond L periods, the average value of earnings is simply $(xLN\Theta - Nc)$ and is independent of the number of cost centers into which the firm is divided up because $n \cdot q$ is equal to constant N by definition. Long-run average earnings of a steady state firm are therefore invariant to the cost center decision. In order to analyze the effect of the cost center decision short-run $(\tau \leq L)$ earnings, rewrite the first line of (10) as

$$(11)\quad \left[x \sum_{i=t-L}^{t-\tau-1} S_i + x\tau N\theta - Nc\right] + \left[-\frac{nc}{L} \sum_{i=t-L}^{t-\tau-1} r_i + Nc(1 - \frac{\tau}{L}(1 - (1-\theta)^n))\right] \quad \text{for } \tau \leq L .$$

The terms in the first square bracket are independent of the number of cost centers but the two terms in the second bracket are not. As the size of cost centers, n, is increased, the value of term $Nc(1 - \frac{\tau}{L})(1 - (1 - \theta)^n)$ also increases for $\tau \leq L$. The first term depends both on the value of n and the pattern of distribution of successful wells among the q cost center actually realized in the $(L - \tau)$ periods beginning $(t - L)$. As the value of n is changed, the short-run expected value of the income of a steady state firm also changes, and the direction and extent of changes depend on the record of exploration activities in the immediate past.

In order to examine the relationship between the expectations of earnings and net cash flow streams, rewrite equations (6) and (10) as

$$\epsilon(I_t/W_{t-L,t-\tau-1}) = \epsilon(X_t/W_{t-L,t-\tau-1}) + nc\left[\phi q(1 - \frac{\tau}{L}) - \frac{1}{L} \sum_{i=t-L}^{t-\tau-1} r_i\right] \quad \text{for } \tau \leq L$$

or $\epsilon(I_t/W_{t-L,t-\tau-1}) - \epsilon(X_t/W_{t-L,t-\tau-1}) =$

$$(12)\quad nc\left[(1 - (1 - \theta)^n)(1 - \frac{\tau}{L})q - \frac{1}{L} \sum_{i=t-L}^{t-\tau-1} r_i\right] \quad \text{for } \tau \leq L .$$

The first term in the brackets is the average value of the second term. The second term is the actual number of successful cost centers during the $(L - \tau)$ periods immediately preceding the forecast divided by L. If the drilling experience of the immediate past has been better than average, this term is negative, and therefore future income tends to be lower than the future cash flow. Thus cash flow is a biased estimate of future income within the next L period, the direction of bias depending on the relative success of the recent exploration. Successful exploration tends to lower the expected income compared to expected cash flow and vice versa. In the longer run--for $\tau > L$--cash flow is an unbiased estimator of earnings.

Now consider the behavior of income under two extreme cases, (1) when the entire firm is considered a single cost center, that is, $q = 1$ and $n = N$, and (2) when each exploration well is considered to be a cost center by itself, that is, $q = N$ and $n = 1$. For $q = N$, expression (9) for income can be rewritten as

$$(13)\quad I_t = x \sum_{i=t-L}^{t-1} S_i - \frac{c}{L} \sum_{i-t-L}^{t-1} S_i - c(N - S_t) = (n - \frac{c}{L}) \sum_{i=t-L}^{t-1} S_i - c(N - S_t)$$

because random variable r_t is equal to S_t in this case. This expression for income is identical to the expression for income under the successful efforts costing system with a single cost center.[7] Indeed, the full cost method with each well considered a cost center by itself is identical to the successful efforts method with the entire firm considered a single cost center. This identity indicates that the fundamental differences between the successful efforts and full cost methods are a matter of degree rather than of kind.

In the first case, with $q = 1$ and $n = N$, the expression for income can be modified to

$$I_t = \left[x \sum_{i=t-L}^{t-1} S_i - Nc \right] - \left[\frac{Nc}{L} \sum_{i=t-L}^{t-1} r_i + Ncr_t \right] \tag{14}$$

Note that the term in the second bracket is the difference between the full cost income of the model presented here and the full cost model in Sunder (1974). This difference is a consequence of the assumption in the latter model that all exploration costs, irrespective of results, are capitalized and subsequently amortized against all reserves. In the present model, on the other hand, it is assumed that all costs of a cost center are capitalized only if it has at least one successful well, otherwise such costs for the cost center are expensed. In the limiting case of $q = 1$ being considered here, there is a small but nonzero probability that all holes drilled in a given period would be dry, leading to expensing of all exploration costs of that period. The second term in the brackets in expression (14) represents the effect of this possibility which gets smaller as the size of the firm N increases. For a very large sized firm, the probability of all wells in a given period being dry is very small and, therefore, the term in the second bracket is zero with a large probability leaving the first two terms of the "true" full cost model developed elsewhere. Since the purpose of the present study is to analyze the effects of the cost center decision on accounting variables, the small difference would considerably simplify analysis without yielding misleading results.

Assets

The asset side of the balance sheet is affected by the cost center decision through the differences in the amounts of capitalized exploration costs and their amortization. As before, it is assumed that the capitalized costs are amortized at a uniform rate over L periods, the lifetime of the discovered reserves.

In period t, the exploration costs of r_t out of q cost centers are capitalized and the rest are expensed as incurred because all exploration wells in the remaining $(q - r_t)$ cost centers are unsuccessful. The capitalized costs are amortized over the following L years, the lifetime of the oil reserves. Lifetime L and net revenue x per well per period are related to each other. It is assumed that the net revenue over the lifetime of a well, xL, is constant and an increase in productive life L can be obtained only by a corresponding decrease in x, the net revenue per period.

For a steady state firm, the balance of unamortized exploration costs at the beginning of period t is

$$A_t = \sum_{i=t-L}^{t-1} ncr_i \frac{i-t+L+1}{L} \tag{15}$$

and its expectation is

$$\epsilon(A_t) = \sum_{i=1}^{L} \frac{ncq\phi}{L} \cdot i = \frac{1}{2} Nc(L + 1)(1 - (1 - \theta)^n) .$$

Now the effect of the cost center decision on average capitalized asset can be examined. To find the rate of change in average assets with n, differentiate (16) with respect to n

$$\frac{d}{dn} \epsilon(A_t) = \frac{1}{2} Nc(L + 1)(1 - \theta)^n \ \ln \left(\frac{1}{1 - \theta}\right) . \tag{17}$$

Since θ, the probability of an exploration well being successful, lies between 0 and 1, $\ln \left(\frac{1}{1 - \theta}\right)$ is a nonnegative quantity. Therefore, the effect of increasing n (or decreasing q, the number of cost centers) on average capitalized costs is always positive. The larger the size of cost centers, the larger the amount of capitalized exploration costs. In a later section of this paper, it is shown that for new firms, the expected income increases with the reduction in the number of cost centers. The higher average income of such new firms is realized by assigning a greater value to their assets. When such a firm arrives in steady state, the income differential due to cost center size disappears (from expression (10b), the long run average income of steady state firms is independent of q) but the difference in accumulated capitalized assets persists.

It may also be noted here that the average capitalization for a single cost center $(q = 1, n = N)$ is

$$\frac{1}{2} Nc(L + 1)(1 - (1 - \theta)^N) \tag{18}$$

which is less than the capitalization under "true" full cost accounting in which case no exploration costs are expensed and the average capitalization is

$$\frac{1}{2} Nc(L + 1) . \tag{19}$$

The difference, $\frac{1}{2} Nc(L + 1)(1 - (1 - \theta)^N)$ gets smaller as the exploration program of the firm (N) gets larger. For example, when $\theta = 0.1$ and $N = 10$, the difference between (18) and (19) is 35 per cent of the total capitalization. When N is increased to 20 and 50, the difference is reduced to 12 per cent and 0.5 per cent, respectively. Therefore, for large organizations, the two models of full cost accounting yield quite similar results. When the number of cost centers is increased, the capitalized values decline sharply. For example, for a relatively small firm which drills ten exploratory wells each year, the average capitalized value of exploration costs when each hole is considered a cost center by itself is approximately θ

times the capitalized value under full cost accounting. By substituting $n = 1$ in (16)

$$\epsilon(A_t/n = 1) = \frac{1}{2} Nc(L + 1)\theta \quad (20)$$

Since the value of θ is usually small (< 0.1), the cost center decision has a significant impact on the balance sheet items of a firm.

The effect of the cost center decision on owners' equity of a steady state firm is identical to its effect on the asset side of the balance sheet. Fewer and larger cost centers result in higher average income being reported in early years of the firm. As discussed earlier, the effect on the asset side of the balance sheet is to capitalize a relatively large proportion of the exploration costs. The corresponding effect on the equity side is to increase the owners' equity by a similar amount. Therefore, the preceding remarks about the effect of the cost center decision on capitalized exploration costs can be extended to the effect on owners' equity. Other things being equal, the owners' equity for the firm with fewer cost centers is always higher. The difference between average capitalized cost of two firms with $n = n_1$ and $n = n_2$, respectively,

$$\epsilon(A_t/n = n_1) - \epsilon(A_t/n = n_2) = \frac{1}{2} Nc(L + 1)\left[(1 - \theta)^{n_2} - (1 - \theta)^{n_1}\right] . \quad (21)$$

The right-hand side of equation (21) is also the difference between owners' equity of the two firms similar in all respects other than the size of cost centers for accumulating exploration costs.

Return on Owners' Equity

In the preceding analysis, the effects of the cost center decision on two balance sheet variables and one income statement variable have been examined. Analysis of financial statements often involves further combination of accounting numbers to yield measures of profitability. Return on owners' equity, the ratio of periodic earnings to owners' equity, is one such measure. For steady state firms, the average value of earnings is not affected by the number of cost centers used by the firm. As shown in equation (10), the average income $(xLN\theta - Nc)$ is independent of q or n. The average value of owners' equity, however, is not independent of the number of cost centers; other things being equal, fewer cost centers result in a higher level of owners' equity. Therefore, the ratio of average income to average owners' equity has a direct relationship to the number of cost centers--the larger the number of cost centers, the higher the value of this ratio.

Consider two steady state firms identical in all respects except the number of cost centers, q_1 and q_2, with $q_1 > q_2$. Therefore,

$$n_1 = N/q_1, \; n_2 = N/q_2 \text{ and } n_1 < n_2 .$$

Let E_1 be the average level of owners' equity for the first firm. The ratio of average income to average owners' equity for the firm is

$$(22)\qquad R_1 = \frac{xLN\theta - Nc}{E_1}\ .$$

From (21), we know that the difference between average owners' equity of the two firms is equal to the difference between average assets and

$$(23)\qquad E_2 = E_1 + 0.5\ Nc(L + 1)\{(1 - \theta)^{n_1} - (1 - \theta)^{n_2}\}\ .$$

Therefore, the ratio of average income to average owners' equity for the second firm is

$$(24)\qquad R_2 = \frac{xLN\theta - Nc}{E_1 + 0.5\ Nc(L + 1)\{(1 - \theta)^{n_1} - (1 - \theta)^{n_2}\}}\ .$$

The ratio of R_1 to R_2 is

$$(25)\qquad \frac{R_1}{R_2} = \frac{E_2}{E_1} = 1 + \frac{0.5\ Nc(L + 1)\{(1 - \theta)^{n_1} - (1 - \theta)^{n_2}\}}{E_1}\ .$$

Since $n_1 < n_2$, the second term on the right-hand side is positive and the average return on owners' equity tends to be higher for the firms which use a larger number of cost centers.

It is important to note here that the performance statistic--return on equity--deteriorates when the number of cost centers is decreased. A decrease in this number tends to move the firm in the direction of full cost accounting which is often believed to result in improved performance statistics. From the analysis of steady state firms, it is clear that one performance statistic--periodic earnings--is on average, neutral to the cost center decision while another, return on equity, can be improved by increasing the number of cost centers. These results, however, may not necessarily hold for new, growing and shrinking firms. In the next section, the effects of cost center decision on accounting variables of new firms which have not yet reached the steady state are examined.

III. New Firms

A new firm is defined as one which has been operating for less than L periods. The firm whose characteristics are analyzed in the previous section is assumed to have been exploring for oil for a minimum of L periods at a constant level. The new firm whose characteristics are analyzed in this section is assumed to be similar to the previous model in all respects except that $t = 1$ for this firm represents the first year of operation. The following analysis is applicable only to $t \leq L$ because after the Lth period, the firm arrives in steady state and is not a new firm any more. Using definitions given in Section II, the net cash flow in period t is

$$(26)\qquad X_t = -\ Nc + x \sum_{i=1}^{t-1} S_i, \quad \text{for} \quad t \leq L$$

and expectation of period t net cash flow τ periods in advance is

$$(27)\quad \epsilon(X_t/S_1, \ldots, S_{t-\tau-1}) = -Nc + x\sum_{i=1}^{t-\tau-1} S_i + r\tau N\theta, \quad \text{for} \begin{cases} t \leq L \\ \tau < t \end{cases}$$

For a new firm, period t income is

$$(28)\qquad I_t = x\sum_{i=1}^{t-1} S_i - \frac{nc}{L}\sum_{i=1}^{t-1} r_i - nc(q - r_t) \quad \text{for} \quad t \leq L .$$

A comparison between expressions (9) and (28) for earnings of steady state and new firms respectively, indicates that the only difference between them is that the index of summation starts from $i = 1$ and not from $i = t - L$ because $t \leq L$. The average value of income of a new firm is

$$(29)\quad \epsilon(I_t) = x(t-1)N\theta - \frac{Nc}{L}(t-1)\phi q - nc(q - \phi q), \quad \text{for} \quad t \leq L$$

$$= x(t-1)N\theta + Nc\{(1 - (1-\theta)^n)(\frac{L - t + 1}{L}) - 1\}, \quad \text{for} \quad t \leq L .$$

Note that for $t = L + 1$, expression (29) for the average income of a new firm becomes identical to expression (10) for the long-run average income of a steady state firm. The difference between average incomes of steady state and new firms is

$$(xLN\theta - Nc) - [x(t-1)N\theta + Nc\{\phi(\frac{L-t-1}{L}) - 1\}] = N(1 - \frac{t-1}{L})(Lx\theta - c\phi) \quad \text{for} \quad t \leq L .$$

The term $Lx\theta$ is the expected net cash flow over L periods from each exploration well and c is the cost of exploration. For a nonruinous operation, $(Lx\theta - c)$ must be positive. Since ϕ is less than unity, $(Lx\theta - c\phi)$ also must be positive. Therefore, the average income of a new firm is always less than the average income of a steady state firm at the same level of exploration activity. The difference, however, decreases linearly with time and becomes zero for $t = L + 1$.

Now we turn to the effect of the cost center decision on average income. Differentiate (29) with respect to n,

$$(30)\qquad \frac{d}{dn}\epsilon(I_t) = Nc(1-\theta)^n \ln\left(\frac{1}{1-\theta}\right) > 0 .$$

Since θ is less than unity, the first derivative is always positive and the average income of a new firm monotonically increases with n, the number of wells per cost center. Fewer cost centers result in higher income on average for new firms and unlike the steady state firms, average income of such firms is not neutral to the cost center decision. The maximum value of average income, obtained with only one cost center is:

$$(31)\quad \epsilon(I_t/q = 1) = x(t-1)N\theta - Nc + Nc(\frac{L-t+1}{L})(1 - (1-\theta)^N) \quad \text{for} \quad t \leq L .$$

For large values of N, $(1-\theta)^N$ approaches zero and the average income for a single cost center can be approximated by

$$(32)\qquad \epsilon(I_t/q = 1) \approx x(t-1)N\theta - Nc + Nc(\frac{L-t+1}{L}) \quad \text{for} \quad t \leq L .$$

The average income of a new firm with a single cost center increases linearly with time until $t = L + 1$ when the firm arrives at a steady state and the average income becomes a constant at $xLN\theta - Nc$.

The maximum possible number of cost centers a firm can have is N with each well considered a cost center by itself. The average income for a new firm with $q = N$ is

$$(33) \qquad \epsilon(I_t/q = N) = x(t - 1)N\theta - Nc + Nc\left(\frac{L - t + 1}{L}\right)\theta \quad \text{for} \quad t \leq L .$$

A change in the number of cost centers from 1 to N reduces the average income of a new firm by

$$(34) \qquad \epsilon(I_t/q = 1) - \epsilon(I_t/q = N) = \frac{Nc}{L}(L - t + 1)(1 - \theta) \quad \text{for} \quad t \leq L .$$

This difference is reduced to zero as the firm matures with time. The effect of the cost center decision on average periodic income is inversely proportional to L, the number of periods over which discovered reserves are exploited. Similarly, an increase in θ, the probability of a successful strike, is accompanied by a decrease in the effect of the cost center on average income of new firms.

During the APB Public Hearings on Accounting and Reporting Practices in the Petroleum Industry, it was apparent that new and small firms tend to prefer the use of larger and fewer cost centers while bigger and well-established firms favor smaller cost centers. If maximizing the level of reported earnings is considered a desirable objective for firms, new firms would prefer using larger and fewer cost centers as the preceding analysis indicates. Reported earnings of mature firms, on the other hand, are on average neutral to this accounting variation because their average income is not affected by the number of cost centers into which the firm's operations are divided. Why, then, do the mature firms tend to favor the use of smaller cost centers? One possible reason can be found in the effect of the cost center decision on the return on equity ratio. Such ratios are widely used to evaluate the performance of firms. As pointed out earlier, the effect of increasing the number of cost centers is to improve the return on owners' equity because smaller cost centers result in less capitalization of exploration costs. If improved reported earnings and rates of return are considered as an objective of a firm in selecting its accounting procedures, mature firms would prefer smaller cost centers which leave average earnings unaffected but improve the rate of return on equity.

Reported earnings of new firms are improved if they use fewer cost centers. To examine the effect of cost center decision on return on owners' equity of new firms, write the expression for owners' equity for such firms:

$$(35) \qquad E_t = E_0 + \sum_{i=1}^{t} I_i - \sum_{i=1}^{t} D_i \quad \text{for} \quad t \leq L .$$

where E_0 = initial owners' equity; D_t = cash dividend paid in period t.

The expected value of owners' equity in period t is

$$(36)\quad \epsilon(E_t) = E_0 - \sum_{i=1}^{t} D_i + \frac{Nx\Theta}{2}(t-1)t + Ntc\phi - Nct - \frac{Nc\phi}{2L}t(t-1) \quad \text{for} \quad t \leq L.$$

Now consider two new firms which are identical in all respects except that they use q_1 and q_2 cost centers respectively and $q_1 < q_2$. The difference between expected values of their owners' equity is

$$(37)\qquad \epsilon(E_t^1) - \epsilon(E_t^2) = (\phi_1 - \phi_2)Ntc(1 - \frac{t-1}{2L}) \text{ for } t \leq L$$

where $$\phi_1 = 1 - (1 - \Theta)^{N/q_1}; \quad \phi_2 = 1 - (1 - \Theta)^{N/q_2} .$$

Since the second term in parentheses, $(1 - \frac{t-1}{2L})$, is always positive for $t \leq L$, $\phi_1 > \phi_2$ implies $E_t^1 > E_t^2$. Since $q_1 < q_2$ implies $\phi_1 > \phi_2$, the expected owners' equity of the first firm with fewer cost centers is always larger. At $t = 1$, the difference between equity of the two firms is small, $(\phi_1 - \phi_2)Nc$, and increases to $(\phi_1 - \phi_2)Nc(\frac{L+1}{2})$ for $t = L + 1$. While the equity base of the first firm increases relative to the second firm as they approach maturity, the income advantage of the first firm is reduced from $(\phi_1 - \phi_2)Nc$ at $t = 1$ to zero at $t = L + 1$. Thus, from $t = 1$ on, the relative advantage of the second firm over the first firm in the rate of return on equity increases. At $t = L + 1$, the second firm has a clear advantage in rate of return because it has the same average income but a lower level of owners' equity. In the first year the first firm has the rate of return advantage and loses that advantage at some point before reaching maturity.

Thus the use of fewer cost centers offers two advantages to new petroleum exploration firms in their early years--higher average level of earnings and higher average return on owners' equity. As the firm matures, the average level of earnings becomes neutral to the cost center decision and smaller cost centers result in a higher rate of return performance. It is therefore hardly surprising, that the smaller, relatively new firms prefer large cost centers while the large corporations in the oil industry tend to favor the use of smaller cost centers.

IV. Concluding Remarks

In the previous two sections, a model to analyze the effects of cost center decision on several accounting variables of petroleum exploration firms has been developed. It has been shown that the use of smaller cost centers yields better measures of performance for mature firms while the opposite is true for relatively new and developing firms. To the extent that firms wish to improve their performance measures, the model explains the known preferences of the two types of firms for different accounting procedures. It is not being argued here that the respective types of firms should prefer one accounting method or the other. The selection of a basis for defining cost centers does not affect the cash flow of the firm. If the market in which the firm operates is efficient in the dispersal of information and if enough information is provided about the results of operations of the firm, the choice of the accounting method should not make any difference whatsoever to the economic situation of the firm. To the extent that such conditions may not be completely satisfied by the existing market mechanism, the accounting procedures may have a real economic effect and therefore be an important decision for the firm. From the controversies that surround the accounting practices in the petroleum industry, it is hard to rule out the possibility that this indeed is the case.

Only two cases--those of steady state and new firms--have been considered here. The model could be extended to include expanding and shrinking firms. The analysis of properties of accounting variables has been limited to the expected values. A useful extension of the model would be to analyze variances, correlations and the predictive power of different variables. A further refinement would be to analyze the effect of cost centers of heterogeneous characteristics within a firm. For the sake of simplicity, however, the analysis of this paper has been limited to homogeneous cost centers.

FOOTNOTES

[1]W. B. Coutts, Accounting Problems in the Oil and Gas Industry (Toronto: The Canadian Institute of Chartered Accountants, 1963).

[2]Robert E. Fields, Financial Reporting in the Extractive Industries, Accounting Research Study No. 11 (New York: American Institute of Certified Public Accountants, 1969).

[3]Ibid., pp. 69 and 72. See recommendations 3 and 5.

[4]Arthur Andersen and Company, "Accounting for Oil and Gas Exploration and Development Costs," Brief presented to the Committee on Extractive Industries of the Accounting Principles Board, in APB Public Hearings on Accounting and Reporting Practices in the Petroleum Industry, Cases in Public Accounting Practice, Vol. 10.

[5]Arthur Andersen and Company, 1972, pp. 17-18.

[6]For further analysis of the properties of the net cash flow series under this model, see S. Sunder, "Properties of Accounting Numbers under Full Costing and Successful Efforts Costing in the Petroleum Industry," Working Paper, Graduate School of Business, University of Chicago, August, 1974.

[7]The properties of accounting numbers under successful efforts and full cost methods have been analyzed in detail in Sunder, op. cit.