513

MARINE RESOURCES OF OIL AND GAS: A REVIEW OF ECONOMIC ISSUES

Prepared for a Workshop on
Ocean Resources Economics
September 13-16, 1981

By Arlon R. Tussing

Institute of Social and Economic Research
University of Alaska
707 A Street
Anchorage, Alaska 99501

and

ARTA, Inc.
2720 Rainier Bank Tower
Seattle, Washington 98101

27 July, 1981

MARINE RESOURCES OF OIL AND NATURAL GAS

Offshore Oil and Gas in the Energy Economy

Petroleum, including both oil and natural gas, became the industrialized world's dominant fuel in the Twentieth Century because fluid hydrocarbons were the cheapest sources of energy for most purposes. Notwithstanding their depleting nature, oil and gas are still the least costly energy sources on a global scale, if we reckon cost in terms of economic resources --- the opportunity value of the necessary labor, capital, and organization. Resources of conventional petroleum in the Middle East alone could sustain current levels of world consumption for several decades at marginal economic costs not much higher than pre-1973 world oil prices.

However, national sovereignties and market organization have conspired to make Middle Eastern oil and other potentially low-cost supplies unavailable outside of the producing countries at prices that have any recognizable connection with economic costs. In addition, because domestic resources of low-cost petroleum in the United States have been explored, extracted, and consumed at an increasing pace for over a century, they have already been depleted to a point where there seems little prospect that new domestic supplies of conventional oil and gas can eliminate the need for oil imports at any foreseeable price. As a result, the economic cost of new domestic oil and gas appears to be significantly higher than the cost of several alternative sources of energy, including electricity from coal and nuclear-fired steam turbines, and liquid or gaseous fuels synthesized from coal, oil shale, or vegetable matter.

The effect is a marginal cost of energy for the United States that is determined by the high price of imported oil. Consumers, investors, and energy producers are adapting to these higher costs in several kinds of ways, among them by ---

> Reducing overall energy consumption;
>
> Substituting some conventional energy forms for others (e.g., coal and natural gas for fuel oil);
>
> Exploiting conventional resources more intensively (e.g., searching for and developing smaller, less productive, or other wise inferior oil and gas fields);
>
> Attempting to adapt familiar energy forms to new uses (e.g., alcohols and compressed gases as transportation fuels); and
>
> Exploiting previously uneconomic kinds of resources (e.g., liquids from oil shale and tar sands; and methane from deep reser voirs, Devonian shale, and geopressurized aquifers).

Each of these adapations to higher prices is a way of accepting higher economic costs. There are, however, two kinds of adaptations that have the potential of circumventing the need to bear higher unit costs --- technological advance and geographic advance. The United States has two major geographic frontiers for oil and gas production: Alaska and the ocean bottom. The chief economic significance of both frontiers is the fact that their conventional oil and gas resources are yet relatively undepleted and, in most cases, unexplored. Unlike the onshore basins of the Lower 48, in other words, it is not true of Alaska or the the Outer Continental Shelf (OCS) that "all of the easy oil and gas has already been found."

The area of the U.S. continental shelf and slope with a sea depth of less than 600 meters is equivalent to about half of the nation's land area; on the average, this acreage is at least as favorable geologically for petroleum as its onshore counterpart. So far, however, only a part of the submerged lands off Louisiana, containing less than 4 percent of the total OCS acreage, has been explored intensively enough to show any evidence of diminishing returns to exploration effort. Even there, the oil and gas-producing industry is only two decades old, and returns to exploration effort, measured in added reserves per foot of exploratory drilling, remain an order of magnitude higher than the onshore Lower-48 average.

The OCS, therefore, offers a fresh new beginning for oil and gas exploration on U.S.-controlled territory --- an opportunity to find and develop much bigger and more productive deposits of conventional oil and gas than most petroleum geologists think remain to be found onshore.

Obviously, searching for and producing oil and gas under the ocean entails costs for equipment and procedures that are not required on land --- very large added costs in the case of deep waters, stormy waters (like the North Atlantic and the Gulf of Alaska), or ice-stressed waters (as those off Western and Northern Alaska). Taking platform costs into account, a typical offshore Louisiana oil or gas development well costs five times as much per foot as the average onshore well in Texas. The unit cost of drilling in the Beaufort Sea promises to be on the order of fifteen to twenty times the onshore Texas figure. On the other hand, we can expect a new offshore Louisiana gas well to produce about forty times as much gas, and a Beaufort Sea oil well to produce on the order of one hundred times as much oil per day as their Texas counterparts.

On balance, then, the great appeal of the OCS is that its nearly untapped resource offers the hope of producing substantial amounts of energy whose marginal economic cost is low, compared with either the price of imported oil or the cost of domestic alternatives.

The OCS has other technical, economic, and insitutional attractions in addition to its geological promise. A line-kilometer of seismic surveying is significantly cheaper to conduct by ship than on land, for example. Comparatively large lease tracts, and the ability to deal with one landlord in a clean arms-length competitive leasing system, are also substantial operational advantages.

The best indicator of the economic promise that major and independent oil and gas producers and others (gas transmission companies, chemical manufacturers, etc.) see in the OCS is the billions of dollars in cash that they have paid in recent lease sales for drilling rights on unproved acreage. (In the 1981 Louisiana offshore sale, Exxon alone exposed more than $700 million.) Industry's revealed optimism about the offshore oil and gas frontier contrasts dramatically with the general reluctance of the same companies to invest in synthetic fuels unless they receive hundreds of millions of dollars in federal subsidies, price suppports, or loan guarantees.

The Burden of Justification

It should be obvious that the social justification for finding and producing offshore oil and gas is identical to the social justification for economic activity generally --- it is a means of producing something that people want at a cost no greater than the value people put on it. A reasonable first approximation of the value of OCS petroleum is the price of its energy equivalent in imported oil --- expectations regarding future OPEC oil prices are clearly a crucial parameter in any explanation of the great sums that oil companies are willing to gamble on OCS exploration programs.

For most goods, the demonstration that their production generates substantial economic rents --- that their market value exceeds their resource cost, in other words --- creates a powerful presumption that production is a Good Thing. Likewise, the need for a subsidy --- the fact that resource costs exceed market values --- normally creates a negative presumption. Either kind of presumption might conceivably be rebutted by a showing that significant "external" costs or benefits exist --- social costs that are not paid by direct consumers of the goods, or benefits that the direct consumers do not receive --- and that these benefits and costs do not cancel each other out.

We can hardly expect a market for rights in unknown quantities of hydrocarbons in unspecified mixtures, producible (if at all) at costs that are currently unknown and unknowable, to be a "perfect" market. In addition, the prices companies are willing to pay for these rights --- like the prices final consumers are willing to pay for fuel --- leave out certain identifiable costs and benefits of OCS production. Some of these "externalities" can be measured or estimated with some degree of confidence, while others are nearly immune to quantification.

The public debate on offshore oil and gas exploration and production is an unusual one, however, because it focuses primarily on comparing the external benefits and costs (like national energy self-sufficiency, or damage to fishery resources), secondarily on the means by which the federal government can maximize the rent it extracts from a given acreage, and hardly at all on the problem of maximizing the first-order or "internal" costs and benefits to society of developing offshore hydrocarbon resources, or of optimizing the total contribution the resource makes to social welfare. The usual presumption seems absent in this debate, that the existence of a market incentive to produce OCS oil and gas truly reflects society's preferences. Even among professional economists with a strong free-market bias, the dominant attitude seems to be that offshore petroleum leasing must be justified by some exceptional social "need" that is not reflected in the price of fuel.

If these observations about public attitudes are accurate, those attitudes themselves are a worthy objects for social-scientific research. Why, indeed, is there a general presumption against developing offshore hydrocarbons? Some parts of the answer are clear ---

1. The fact that the resource is controlled by the federal government, under a regime in which it is normally unavailable for development, makes an oil and gas lease sale appear to be an affirmative "public" act that requires a "public" justification --- a justification, that is, in terms of externalities.

2. In the absence of wellhead price controls, OCS oil and gas are "price-takers" at the OPEC-equivalency price. As a result,

the savings to society that result from substituting lower-cost OCS oil and gas for OPEC oil, synthetics, or other higher-cost alternatives, do not accrue to fuel consumers as such. Thus, there is no perceptible consumer-advocate constituency favoring OCS production.

3. No other clearly defined private interest benefits from OCS production either, because the leasing system has been designed expressly to allow the landowner (the federal government, which is everybody and hence nobody) to capture the entire economic rent. This system is not totally efficient in accomplishing its goal; if it were, not even the oil companies would bother to advocate OCS development. But imperfect as the leasing system may be, it has been effective enough to restict the private constituency favoring offshore petroleum development to something far smaller and far less zealous than the potential rents would suggest.

4. State and local governments do not share in federal OCS revenues, as they do in the revenues from onshore mineral leasing and sales, timber sales, and the like. Affected communities thus seem only to bear the external costs, real or imagined, from offshore petroleum development, and receive none of the direct benefits. It is not surprising, therefore, that California, Massachusetts, and Alaska politicians have been in the forefront of opposition to acceleration of OCS development.

It is instructive to compare the power and determination of the lobbies that support protection and subsidies for the merchant marine (which reduce the national income) or the tobacco growers (who may rank first among all industries in the negative externalities they generate), with the near-invisibility of the political forces advocating OCS development, whose potential share of the national product is greater by two orders of magnitude. Even the enthusiasm that offshore leasing now enjoys in the Reagan Administration points up the burden of adversity it ususally carries: No Interior Secretary prior to the incumbent, who is an ideological fanatic, has truly been an **advocate** of OCS oil and gas on the basis of its first-order economic advantages to the nation.

Politics of the Research Agenda

Any plausible agenda for economic research related to offshore oil and gas has certain inevitable components. Some of the most conspicuous issues are marine-resource issues only incidentally, or relate to offshore petroleum in exactly the same way they relate to petroleum generally. The projection of national and global energy demand, or the level of world oil prices; analyses of petroleum industry structure and behavior; and the effects of oil or gas price controls and petroleum-industry tax policy, are all such instances, and will not be pursued in detail here. The chief categories of research for which the offshore petroleum resource offers clearly distinguishable issues include ---

1. The character and size of the resource base, and the supply function (i.e., the schedule of production rates or volumes vs. costs) that flows from the character of the resource;

2. The schedule and pace of resource development;

3. The system of assigning exploration and production rights, and for structuring and allocating resource rents (Under present institutions, these issues are largely summed up by a consideration of "the leasing system."); and

4. The external costs of offshore petroleum exploration and development, largely in the form of damage or the risk of damage to fisheries and other living resources of the sea and its estuaries, shorelines, etc.; aesthetic values; and the social stability of small coastal communities.

While most scholars would likely agree that these four categories contain most of the vital issues of economic analysis and social policy, any ordering of the detailed research agenda is an intensely political task, which cannot help but reflect one's ideology and predispositions. Better information about the offshore petroleum resource base, for example, can have several legitimate analytical and policy purposes. Much of the current demand for an "inventory" of OCS oil and gas resources, or for "knowing what's out there" prior to leasing stems , however, from the attitude that offshore petroleum development is a "public good" (or "bad") whose necessary justification is its ability to serve some exceptional collective "need," or from the notion that accurate preleasing information is essential to enable the federal landowner to extract the last measure of rent from each acre it leases.

A supply function for offshore oil and gas would, similarly, have many analytical and policy uses, but the most insistent clients for such information have been those who wanted to create complicated leasing schemes, or stratified tax and price-control systems (like the so-called windfall profits tax and the Natural Gas Policy Act) in order to fine-tune the federal government's attempt to capture the economic rents generated in production, or transfer them to consumers.

None of these premises or objectives is of self-evident merit. One might rank the size of the welfare benefit created by offshore petroleum production as a higher concern than the ability of the federal treasury to capture the whole of that benefit. And one might just as easily believe that the willingness of oil companies to pay up-front cash for drilling rights establishes a prima facie presumption that society will indeed benefit from leasing the tract in question. If competition for the tract exists among oil companies, these premises would make the amount of geological information in the files of the Interior Department or the beliefs of U.S. Geological Survey (USGS) staff about the probable reserves contained in the tract of little relevance to the decision whether, and at what price, the tract should be leased.

The relative importance of the various other categories of information or analysis concerning OCS petroleum depends, similarly, on the policy purposes for which one wants them. Subject to this warning, the remainder of the present paper surveys some of the salient issues.

The OCS Petroleum Resource Base and its Supply Function

Estimation of the petroleum resource base. Most petroleum geologists believe that all of the hydrocarbons found in the earth's crust are products of organic sediments that have been subjected to great heat and pressure. Such deposits occur only where suitable "source rocks" occur in the right relationship with suitable "reservoir rocks" having an effective "trapping mechanism" to prevent the hydrocarbons from escaping into the atmosphere and/or oxidizing.

The total hydrocarbon resource base **in areas with a long petroleum-producing history** is usually estimated by plotting cumulative production or additions to proved reserves against some proxy for exploration effort (such as feet of exploratory-well drilling); this function is then fitted to a logistic curve or other function chosen a priori, which is then extrapolated to a point that corresponds to the complete exhaustion of the resource. The area under the curve represents the **total original** endowment of recoverable resources, and the area to the right of today's level of exploration effort represents the **remaining** recoverable resource.

In many developed petroleum-producing areas, the fit of such curves and their predictive power have been excellent. Unfortunately, this methodology performs much **too** well; the same family of curves seems to fit continental and global exploration experience over many decades --- something it should **not** do in view of the great differences among areas, and changes over time, in exporation and extraction technology, relative prices, and development institutions.

The volume of economically recoverable oil and gas in frontier areas is generally estimated by analogy to well-studied portions of already-explored and largely depleted regions, on the basis of the estimated volume of various categories of source rocks and the presence or absence of suitably situated reservoir rocks. The most ambitious resource-assessment program of this kind is that of the USGS, which publishes basin-by-basin projections of ultimately recoverable oil and gas for both onshore and offshore regions at five-percent, fifty-percent, and ninety-five percent confidence levels.

The basin-by-basin projections of the USGS are revised periodically on the basis of new information, new definitions (the cut-off water depth in offshore areas, for example), changes in the professional staff's theories of regional geology, and changes in methodology. The USGS also makes estimates for smaller areas --- including single lease tracts for use by the Bureau of Land Management (BLM) in administering lease sales --- employing essentially the same procedures, but on the basis of more location-specific data.

Both steps in the estimation process --- extrapolation of total reserves in regions with a substantial production history, and the process of analogizing to frontier areas --- deserve critical scrutiny. To my knowledge, however, no one has attempted a retrospective evaluation of the USGS forecasting methodology on the basis of the results of subsequent exploration. In the meantime, the USGS estimates should be viewed only as a ranking of various areas by one highly competent team of geologists in terms of their **relative** attractiveness for exploration.

Even apart from the non-existence of any empirical check on USGS performance, there are several reasons not to take anyone's projections of absolute resource volumes for offshore and other frontier areas too seriously. First, the estimates are for an arbitrary but only vaguely defined fraction of the "in-place" hydrocarbons in each region. Methane, for example, is found everywhere in the earth's crust, including volcanic rocks --- in apparent contradiction to the dogma that crude oil and natural gas are exclusively of biological origin. The Devonian shales of the Appalachian region alone, and the geopressurized aquifers along the U.S. Gulf Coast, are each believed to contain about three orders of magnitude more methane than the USGS estimates of the total remaining domestic resource of "natural gas."

One problem, therefore, is that the resource-base estimates expressly refer only to that part of the in-place resource which is discoverable and economically recoverable **with current technology, under current economic conditions.** The meaning of both of these phrases is nebulous, and they become hopelessly ambiguous in connection with the ultimate size of a resource, most of which will inevitably be produced (if at all) with different techniques and under different economic conditions from those that prevail today.

In this context, the Survey's recent decision to publish its estimates in probabilistic terms is both a service and a disservice. Posting a broad range of plausible resource values between the 5-percent and the 95-percent confidence levels indicates clearly that such projections are essentially guesses, and reduces the tendency of unsophisticated readers to accept them for planning or policy purposes as if they were precise accounting measures. The use of percentage confidence intervals, on the other hand, tends to mislead more sophisticated readers by suggesting that there is actually a 90-percent probability that the oil or gas ultimately recovered will actually fall between the two estimates.

This is not a correct inference, because the method the USGS uses to arrive at its numbers does not treat **all** its variables, parameters, and structural relationships as random variables. The basic geological theories behind the method (that petroleum is exclusively of biotic origin, for example) do not vary, nor do the chemical and physical boundaries of the substances it considers as "crude oil" or "natural gas," nor does the content of "current economic conditions" or "available technology." While the volume of oil or gas that is recovered can be expected to depart somewhat from the USGS estimates because of theoretical errors, changes in the physical or chemical characteristics that define the limits of "crude oil" or "natural gas," the development of geophysical techniques for locating "stratigraphic traps," or future changes in real energy prices, the probability of such developments is **not** incorporated into the USGS method for establishing the "probable" range of resource volumes.

The link between the "resource base" and the outlook for discovery and extraction of hydrocarbons. Even if the estimates of the economically recoverable oil and gas resource in each region by the USGS or some other institution were both unambiguous and accurate --- say, within a factor of two, these estimates themselves would be of little use still for economic analysis or policy formation, except as an index of the relative attractiveness of different regions as exploration targets. We would still have little systematic knowledge about the effects of deciding to lease a given OCS area on the time profile of exploration, development, and production effort, or on the volume of hydrocarbons that will be produced over a given period.

Other variables besides the total resource of a whole region (or even its average resource volume per unit of area) are vital for projecting discovery and production costs or the timing and rate of future production. It is crucial, for example, to know whether surface geology and seismic surveys indicate that the 1-billion barrels of crude oil in the "median" estimate for a given OCS area is likely to be contained mostly in one or two giant structural traps, in a few large stratigraphic traps that can not be identified from the surface, or in dozens of smaller fields and reservoirs of various kinds.

While contemporary geological science does have a great deal to say about these issues, this knowledge does not seem to a systematic input to the Interior Department's development and production scenarios for the current generation of OCS lease sales. Organization; manpower, materials, and equipment procurement and mobilization; exploration and information-processing sequences; and institutional rhythms (including formulation of impact statements, permitting, and litigation) will interact with the geological peculiarities of a particular area to dictate the pace of exploration and development. The effect of all these factors will be modified at random, moreover, on the basis of early discoveries or the lack of them.

Microeconomics of petroleum exploration and production. Estimates of ultimately recoverable offshore oil and gas resources may not have much usefulness for economic analysis or policy formation, in light of their definitional and methodological uncertainties and the murky process by which they have to be translated into variables that have operational consequences --- proved reserves, for example, or barrels per day of production over a given period. The most useful microeconomic data, however, are those that could be assembled to make up a series of supply functions for offshore hydrocarbons --- in other words, the expected combinations of fixed and variable costs at various plausible rates of production.

Different dimensions of these supply functions can be viewed as mapping the long-term marginal costs of OCS oil and gas production instantaneously and in response to movement along several successive variables ---

1. Additional development and depletion of known reserves on tracts that are currently under lease.

2. Additional exploration investment on currently leased tracts, and on other tracts currently or presently available for lease;

3. Exploration and development of the latter tracts;

4. The availability of additional tracts for lease;

5. The increase in knowledge (including geological knowledge obtained in the exploration and development of earlier prospects) and the improvement of technique; and

6. The depletion of prospects that are "easiest" to find and produce.

Unfortunately, we do not even have a satisfactory recent point estimate for the marginal economic cost of OCS oil or gas. Even a single-point marginal resource-cost estimate based upon information form all post-1970 lease tracts would be the beginning of wisdom in comparing the social cost-effectiveness of OCS leasing with conservation, coal-conversion, synfuels, or whatever, or in assessing the supply effects of the Windfall Profits Tax, natural-gas price deregulation, etc.

In principle, one can impute what petroleum-producing companies **expected** the marginal cost of oil and gas to be on the more-recently leased OCS tracts --- acreage still without significant discoveries --- but only by analyzing the successful bids in the light of what is known about the geology of individual tracts, and only by making heroic assumptions about the discount rates used by the companies, and what they in turn assumed about the course of future oil and gas prices. Mapping successive dimensions of the OCS oil and gas supply function in the order set out on page 16 would require increasing amounts of geological and engineering information (or increasingly arbitrary assumptions), much of which would have to be presented and processed in probabilistic form.

The work required to produce such supply functions would be stupendous. Exploration effort, for example, is not homogeneous. The process of adding to reserves is a sequence of analytically-separable phases --- surface geophysical and geological exploration, stratigraphic testing, new-field exploration drilling, delineation drilling, and field development --- the mix and relative costs of which are highly variable. Before these stages can be comprehended in the construction of oil and gas supply functions, however, we need a better theoretical understanding of the relations among them, and the way in which expected petroleum prices, the current reserve-to-production ratio, the availablity of "wildcat" acreage, tax treatment, and regulations regarding unitization and conservation, bias the mix of current exploration investments toward one phase or another. The supply functions for inputs to petroleum exploration and development, and particularly the lags in their supply response, also require better analysis --- if only because the alleged shortage of drilling rigs, tubular goods, and petroleum engineers is a frequent weapon in the idoelogical armory of those who deny the possibility of significant energy-supply responses to accelerated OCS leasing or price decontrol.

In each phase of exploration, moreover, different teams of geologists and engineers are likely to interpret the same data very differently, and to approach a given exploration play with a different geological theory and a different exploration strategy. There are many anecdotes about instances in which one exploration team has made a big discovery on a play that has been thoroughly worked over and rejected by many others. Such differences in judgment are also reflected dramatically in the range of bids a single tract will receive in a single offering,

I am not aware of any systematic analysis of the importance of "multiple perspectives" in petroleum exploration, or of its policy implications. To what extent do variations in the number of bidders on oil and gas lease tracts and the range of bids on individual tracts truly reveal the existence of different geological evaluations, or different exploration strategies?

If multiple perspectives do indeed have a powerful effect on the discovery outlook, perhaps the duplication of effort involved in competing pre-leasing geophysical programs, and the fragmentation of control over prospective petroleum-bearing structures through leasing small tracts, are not as uneconomic as most scholarly commentators have assumed. The same issues are of course central to any evaluation of proposals for a "two-stage" leasing systems or pre-lease governmental exploration programs.

A greater number of competing exploration teams will surely increase the likelihood of exploratory success; but there are surely diminishing returns to this effect as well. Where, for example, does duplication of effort or fragmentation of the target acreage begin to offset the advantages of multiple perspectives? Increasing the number of of teams working a single frontier play from one to two probably has a powerful effect on the expectation of success, but what about an increase from seven to eight, or seven to fifteen?

The Long-Term Demand for Natural Hydrocarbons and the Optimum Rate of Depletion.

There is a body of orthodox economic theory that deals with the optimum rate of depletion of a mineral resource. Decision rules that flow from that body of theory depend, inter alia, on (1) the choice of a discount rate, (2) the expected long-term price trend for the resource product (reflecting growing scarcity or abundance of the product and/or its substitutes), and (3) the rate at which depletion raises the marginal cost of the resource product.

The lack of consensus on (2) and of useful information on (3) would make the existing analytical apparatus practically useless for making policy about the rate at which OCS acreage should be leased, explored, or depleted, even if the real-world analytical problem were not complicated by non-market price determination, royalties and Windfall Profits Taxes, trade barriers, questions about the national-security or foreign-exchange premium to be imputed to domestic production, etc. Yet no intellectually respectable alternative is in sight.

In the absence of an appropriate body of theory, even professional economists often tend to speak casually of the alleged failure of market prices to take account of the "user cost" of exhaustible resources (the present value of depleting the resource some time in the future, rather than today), and the imperative for saving a supposedly appreciating stock of goods for "future generations" or for "a time we really need it."

Perhaps we can excuse biologists and engineers this kind of nonsense, but economists ought to be aware that ---

1. There are already several acceptable long-term substitutes for every use of conventional petroleum at costs in the vicinity of, if not lower than, its current world price;

2. The world's known resources, and the known U.S. resources, of "near-petroleum" (heavy oil; oil shale; tar sands, methane in deep basins, Devonian shale, geopressurized aquifers, and hydrates, for example) are equivalent to decades, hundreds, and sometimes thousands of years of consumption at present rates;

3. Technical advance will undoubtedly widen society's technological options regarding both the production and the consumption of energy; and finally

4. Future generations will probably be richer than we are.

A related truism found in the classical economic literature, but whose relevance to the present is doubtful, is the notion that the discount rates private firms apply to decisions regarding the exploration, development, and production of exhaustible resources are higher than society's true rate of time preference and that, as a result, private firms would deplete OCS oil and gas resources too rapidly. The notion that industry, left to itself, would develop hydrocarbon resources too rapidly is implicit in the very idea that the government should have a "leasing schedule."

In the absence of that questionable assumption, however, poor Mr. Watt is almost right notwithstanding his lack of finesse, in trying to make the entire OCS available for leasing now, with tracts put up for auction or otherwise disposed of whenever serious interest appears. His approach has a more respectable theoretical foundation than the previous policy of the Interior Department, which has been deliberately dribbling out a mixture of good, bad, and indifferent prospects selected on wholly non-economic criteria.

The assumption that industry's discount rate is higher than that of society has a certain intuitive appeal, as does the notion that it is the "social discount rate" that ought to be reflected in the exploitation of publicly-owned resources. These propositions have no operational meaning, however, in a world where no consensus is possible on the true discount rate for either private or social decisions, and in which "society's" only operational proxy is the federal government. What reason is there to believe, in particular, that elected officials or public servants --- say, either Mr. Andrus or Mr. Watt --- have time horizons that are longer, closer to that of "society as a whole" (whatever that may be), or more rationally based than those of the multinational oil companies?

Leasing Policy

Strategies for leasing oil and gas exploration rights have recieved exceptionally intense scrutiny in the last decade, and a massive theoretical and analytical literature exists comparing various bidding systems for their effect on investment, the time profile of production and the volume of hydrocarbons ultimately recovered, and above all, the present value of the landlord's income.

One part of this literature seems to confirm the superiority of conventional cash-bonus bidding (with, perhaps, a shift from an _ad valorem_ royalty to a net-profit-share royalty), but the larger part of the recent theoretical effort seems to present a strong case for radical changes in bidding and leasing arrangements --- two-stage leasing, for example, and royalty or net-profit share rates as the bid variable. These analyses have provided the foundation on which Congress and the Alaska legislature directed their respective resource-management agencies to utilize several different bidding systems.

It appears, however, that the responsible personnel in both the government land-management agencies and in the industry abhor such innovations, and that independent exploration companies (who were among the purported beneficiaries of the lower fornt-end charges under the new system) shun royalty-bid sales even more than the major operators, and even more than they did cash-bonus bidding. The reasons for the nearly universal opposition of those who must operate the leasing system are not clear, but they may be as interesting and as important as the outcome of the various mathematical models that provided the justification for the new procedures. (Some of the potential mischief that multiple bidding systems and variable royalties can create is about to surface in the Beaufort Sea, where the companies will surely propose to establish production units that include tracts leased under several different arrangements.)

Government lease administrators, like industry explorationists, tend to hold traditional views and to favor the conventional system of sealed bonus bids. The case for the traditional leasing system includes the proposition that bidders regard geological risk as a fair gamble. Oil companies are, arguably, neither significantly risk-seeking nor significantly risk-averse and do not, therefore, on the average and in the long run, discount their lease bids to reflect exploration risk.

Thus, if the traditional view is valid, wider dissemination of geophysical and geological information among prospective bidders before each lease sale is not likely to have a significant long-run effect on either the aggregate value of the winning bids or on the outlook for exploration success. The same view also implies that the amount of geophysical and geological information the government as lessor has for its own use will not significantly enlarge its lease revenues, unless the number of bidders on each tract is very small.

Both Federal and State land-management personnel seem to favor this analysis with respect to the bidding system, but they are nevertheless constantly seeking the authority to require operators to disclose more and more proprietary information, on the ground that "we need to know what we're selling," and that such information is necessary in order to decide which bids to reject as too low. If the companies truly regard exploration as a fair gamble, and the market for exploration rights is workably competitive, however, it is not clear to me just how official behavior would or should be affected by the possession of additional geological information, or what effect it would have on the aggregate outcome of the leasing process.

Other leasing-policy issues that are amenable to systematic analysis but which have received far less attention than bidding systems include the optimum size and number of tracts to be offered in a sale, and the term a lease may be held prior to commencement of drilling, unitization, development for production, or commercial production.

External Costs of Offshore Petroleum Operations

Evaluating the adverse effects of offshore oil and gas exploration and production is an area that is not particularly to rigorous economic analysis, because it involves a comparison of uncertain but quantifiable commercial resource values with uncertain and non-quantifiable environmental, aesthetic, and emotional values. It is, of course, an ideologically charged area, in which the case for commercial oil and gas production is handicapped by the factors I enumerated on pages 6 and 7.

The most conspicuous issues under this category relate to (1) the short- and long-term effects of discharges of oil and other materials into water or the air on the marine environment, and to the size-frequency distribution of discharges from various types of petroleum-related offshore activity in various environments; and (2) the short-and long-term effects of disturbing the ocean bottom, wetlands, estuaries, beaches, and the onshore coastal zone by drilling, dredging, laying of pipelines, platform and terminal construction, and the like.

In the absence of dramatic new findings regarding cumulative damage from hydrocarbons discharges, the potential economic benefits from oil and gas production almost certainly probably swamp out the expected value of all quantifiable damages that might result from such discharges. In many cases, indeed, they are likely to overwhelm the gross economic value of the assets placed at risk.

Even if the expected quantifiable economic damages per unit of output (e.g., per billion barrels of oil produced) are significant, they still may not be large compared to the expected damages from alternative energy-related activities, the most conspicuous of which is shipment of onshore-produced or imported oil by tanker, but which include onshore oil and gas production, the mining and use of coal, and the production of synthetic fuels. A number of studies have compared the volume of residuals produced by various modes of energy production, transportation, and conversion --- in each case I have examined, offshore petroleum comes out as the second cleanest (after, ironically, nuclear electric generation, which is inferior only with respect to waste-heat discharges). I have not seen any systematic analyses, however, of the marginal rates of exchange among various energy alternatives in terms of their environmental impacts.