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BENEFIT-COST ANALYSIS AND THE NATIONAL OCEANOGRAPHIC PROGRAM

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In 1964 the National Academy of Sciences—National Research Council published a monograph entitled *Economic Benefits from Oceanographic Research*.¹ The study was issued with considerable fanfare, and it has attracted wide attention among scholars in the diverse fields associated with oceanography and in both the popular and professional press. It is not surprising that it should—the list of authors includes some of the most distinguished names in the field of oceanography. The field itself has been the object of intense interest in both executive and congressional branches of the Government—so much so, that the governmental research effort in the field has been designated as a National Oceanographic Program. Research expenditures on oceanographic research supported by the federal government are growing rapidly. In 1954 the expenditures were 24 million dollars and projections of the Interagency Committee on Oceanography indicate they will increase to 350 million dollars by 1972.

While the authors of the monograph are to be commended for a courageous attempt to develop an objective basis for appraisal of government research in a most difficult area, the results must be termed disappointing. The disappointing results may be attributed to the inevitable “softness” of data and data sources in any field in which the distance between basic scientific research and commercially usable end products is as great as in oceanography. In part it reflects the unavailability of a common yardstick to measure the value of commercially usable outputs and of those outputs that may ultimately prove of incalculable benefit in a material sense, but which for the moment simply represent additions to knowledge. But the study also suffers from errors in concept and fact to a degree not warranted by the present state of knowledge.

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1. National Academy of Sciences, National Research Council (Pub. No. 1223, 1964). The authors are indebted to Dr. M. B. Shaefer for helpful interpretations of the NAS study and for pointing out several numerical errors in the original draft of this paper. His assistance does not, however, indicate agreement with the conclusions.

The difficulties of softness of data and data sources and lack of a common yardstick reflect inherent constraints on the accuracy of numerical results; the authors' treatment can be disputed only on the basis of specific assumptions as to the reliability of particular sets of data. The latter weakness is less excusable, since the internal logic of benefit-cost analysis and the essential requirements of its proper application have been thoroughly explored in the literature: first in the field of water resources,² and more recently, in relation to a wider range of government investment programs.³

The application of benefit-cost analysis to oceanographic research is both legitimate and illuminating. In many respects, it illustrates the most difficult types of appraisal problems in the field of public investment. There are tremendous gaps in man's knowledge of physical parameters and in his ability to relate physical to economic magnitudes. The investment required to carry on productive research and development in the ocean environment is extremely heavy and the pay-off period is both long and subject to a high degree of uncertainty. Most oceanographic research therefore, is "Big Science."⁴ In addition, a relatively high proportion of the research must be considered basic rather than applied at the present level of understanding. Both facts suggest that massive government participation and financial support is required if the job is to be done adequately. Clearly, one cannot rely on the market mechanism to provide sufficient stimulus to private industry or the university community to do the necessary level or type of research and development work. But oceanography is only one claimant seeking recognition at the public till, and some method of establishing priorities within the field itself, and of justifying specific levels of research effort, must be developed.

In this Article two weaknesses of the National Academy of Science (NAS) study will be discussed: (1) conceptual errors, and (2) questions of fact and figure. There is every reason to extend the application of a technique for evaluating choices that has proved so useful in other areas, particularly if oceanography is to justify the intensified attention of professionals in the field and the expanded activity demanded by the general public and financed by the

2. For an excellent summary of literature on the application of benefit-cost analysis to water resources projects, see Lee, *Local Government Public Works Decision Making*, chs. 3, 4 (Institute in Engineering-Economics Systems Report No. EEP-9, 1964).

3. See, *e.g.*, Dorfman (ed.), *Measuring Benefits of Government Investments* (1965).

4. The concept of "Big Science" is described in Weinberg, *Criterion for Scientific Choice*, *Physics Today* 42 (March 1964).

federal government. If benefit-cost analysis is to be applied to oceanographic research and its fruits, however, its application should be done properly and with full attention to both its potential and its limitations. To the extent that the NAS study falls short of these requirements, it could do more harm than good, not only to a program that deserves greater support, but also to the broader use of benefit-cost analysis as a tool of economic evaluation.

The NAS panel attempted to identify and estimate the economic value of benefits stemming from oceanographic research after a ten-year period of expenditures, and to compare these estimates with the cost of the research. The benefits consist of increases in physical production of food and minerals from the ocean and cost savings from improvements in sea transportation, long-range weather forecasting, near-shore sewage disposal, and near-shore recreation. Both costs and benefits are discounted at ten per cent to the time at which research costs are actually incurred and, alternatively, to present values.

The NAS authors indicate three purposes: (1) to measure the contribution of the oceanographic program to the well-being of the United States; (2) to provide a very rough basis for comparison of returns from this program with those that might be obtained from alternative uses of the funds to be expended; and (3) to suggest a conceptual and computational framework that could be employed by others who might make quite different judgments about the numerical values used.

The NAS authors state that their estimates are based only on "tangible and foreseeable economic results of federally supported oceanographic research."⁵ No attempt has been made to forecast breakthroughs or to place dollar values on national defense or on the human satisfaction derived from greater understanding of the oceans and of life in the sea. No estimates of economic values for

5. National Academy of Sciences, National Research Council, *Economic Benefits From Oceanographic Research 2* (Pub. No. 1228, 1964). The NAS panel estimated that a total expenditure of 1.389 billion dollars on oceanographic research over the next ten years would result in total economic benefits of over 6 billion dollars, both values being discounted to the present. These benefits would be derived from increased United States and foreign fisheries production, amounting to 2.418 billion dollars; increased mineral production, worth 336 million dollars; and reductions in shipping costs amounting to 958 million dollars. The panel estimated that the projected expenditures on oceanographic research would also result in improvements in long-range weather forecasting worth 1.354 billion dollars, reductions in near-shore sewage disposal costs worth 321 million dollars, and improvements in near-shore recreational opportunities worth 677 million dollars.

several potentially useful "outputs" of oceanographic research have been included where the necessary research is normally carried out by private firms or where even rough data are lacking.

I

ELEMENTS OF BENEFIT-COST ANALYSIS

A full review of the principles of benefit-cost analysis is beyond the scope of this Article.⁶ However, a brief restatement of a few key concepts is essential. Basically, benefit-cost analysis represents a simulation of the operation of a competitive market economy to provide a basis for allocation of resources in sectors where for any of several reasons, the market mechanism will not function properly. In some instances the private sector will not undertake investments that would clearly yield benefits greater than costs because no effective way can be devised to charge for the former. In other situations, economies of scale may be available only to a public agency, or for technical reasons only one or a few operating units can be permitted. In still others, the basic "rule of the game" in private enterprise that all costs be borne by those who inflict them on society may be violated. For example, in water pollution, downstream costs are difficult to identify and quantify, and costs are even more difficult to levy on those who cause them. Finally, many benefits from social investments, including research and development, simply cannot be measured in economic terms. Among others, the accumulation of knowledge for its own sake, an essential element in man's restless striving for fulfillment, defies quantification in monetary terms, yet it can hardly be ignored as an output of many types of government, academic, and industrial research.

Benefit-cost analysis represents a technique for choosing among alternative uses of resources for varying objectives. The maximization of net national product (the money value of the net output of goods and services in the economy as a whole) is the most common of the objectives sought. It rests upon two essential comparisons: (1) a comparison of present with future benefits, via discounting of more distant benefits to present values; and (2) a comparison of benefits with costs, the latter representing the value of goods and services that could have been produced with the resources to be devoted to the use in question. Assuming proper meas-

6. This has been set forth in detail in Sewell, *Guide to Benefit-Cost Analysis* (1961).

urement, an efficient program requires: (1) that the program as a whole show a ratio of benefits to costs greater than unity; (2) that each separable part of the program show benefits in excess of costs; and (3) that the scale of the program be such that marginal net social benefits are zero, that is, benefits less total costs are maximized.⁷

II

CONCEPTUAL WEAKNESSES IN THE NAS REPORT

A. Gross and Net Benefits

There is much evidence that the authors of the NAS study, though well-acquainted with the words of benefit-cost, were much less familiar with the music. The result is a series of conceptual errors that severely damage the usefulness of the entire exercise. A basic and elementary principle is that benefits are computed in net terms; that is, the addition to market value resulting from the additional output of goods and services minus the costs of associated factors of production required to produce it. In several places—notably in the valuation of outdoor recreation, mining, and commercial fishing—the authors of the NAS study appear to have computed benefits in gross terms; or to have made grossly inadequate estimates of the associated costs of using resources in the ways indicated if the percentages of benefits not allocated to oceanographic research in Column I of Table I are of the NAS report presumed to include associated factor costs. (Dr. M. B. Schaefer, one of the authors of the NAS study, informs us that the latter interpretation is correct.)

The fisheries example affords an excellent illustration of the magnitude of the error involved. Suppose that an increase in oceanographic knowledge opens up an opportunity to exploit profitably a previously untapped fishery population. The increase in national product resulting from this technological shift in knowledge clearly is not measured by the market value of the increased catch alone. Setting aside for the moment the validity of the estimates of increased physical production of fishery products associated with increased oceanographic research, it should be evident that only a fraction of the gross increment to market value of fish landings could be considered a net benefit, since additional labor and capital

7. For a summary of alternative ways of calculating benefits and costs to determine optimal scale and composition of a program, see Lee, *op. cit. supra* note 2, at 57-107.

will usually be required to translate that knowledge into additional production.

The inshore and offshore fisheries of the United States are presently subject to unrestricted entry. Since there are no legal or technical barriers to the formation of new fishing units, any increase in productivity resulting from increased oceanographic knowledge and its impact on production functions would lead to increased net returns to the individual vessel and then to an increase in the number of fishing units. A new equilibrium will be restored only when average vessel earnings are again at the minimum level required to maintain existing investment. One of the most serious problems of the marine fisheries is the inherent tendency for all economic rent attributable to the resource to be dissipated by excessive entry. The existence of this inherent tendency is well documented in both theory and empirical studies.⁸

Surely the problems of entry imply that the net benefits to be attributed to increased oceanographic research are likely to be very small—at least, no larger than the additional net return to the old and new units engaged in the fishery. More fish would be obtained, but only by foregoing other things that could have been produced with the additional labor and capital attracted to the fishery. Moreover, if the increased fishing effort induced by cost-saving innovations stemming from oceanographic research leads to levels of fishing effort at which the yield capabilities of the fish stocks concerned are exceeded, no additional output will be realized and the “savings” will be dissipated by overcapacity in the fishery. Hence, the NAS estimate of a discounted value of 207 million dollars for the increase in net returns from fishing will be grossly in error even if one accepts without question the adequacy of the assumed link between the additional research and the additional catch.

Precisely the same criticism would apply to the calculation of benefits from mineral production resulting from the production possibilities opened by research in oceanography. Benefits from outdoor recreation were also calculated in gross terms. Again ignoring the realism of the assumed relation between oceanographic research and the increased value of outdoor recreation, the NAS use of total expenditure figures is unacceptable in any kind of benefit-cost analysis of outdoor recreation. This has long been recognized in the

8. The literature, including a summary of the pioneering work of H. Scott Gordon and A. D. Scott, is summarized in Crutchfield, *The Marine Fisheries: A Problem in International Cooperation*, Am. Econ. Rev. 207 (1964).

literature, and accordingly a number of difficult but potentially useful and analytically correct techniques have been developed to measure, at least in ordinal terms, the money value of increments to outdoor recreation.⁹ It should also be noted that the recreation benefit in the NAS report is apparently calculated on the basis of existing expenditures, not on the increment to expenditures expected to result from additional oceanographic effort. If this correction is made, the spectacular benefit-cost ratio realized in this sector diminishes drastically—from eight-to-one to four-tenths-to-one.

The opportunity cost concept, that is, the value of output foregone by use of associated factors of production, is involved in a somewhat different type of error in the calculation of benefits to shipborne foreign trade. For example, rerouting to reduce weather losses is likely to involve additional storage costs, delays in port, and, in some cases, increased fuel costs. Similarly, reduction of turn-around time may require changes in operating costs as a result of altered maintenance and fuel requirements. It seems highly unlikely that all of the savings listed are purely additive. Moreover, ocean shipping, like other capital-intensive industries, has experienced marked technological advances in a variety of fields, some of which offer alternatives to improved oceanographic knowledge of the type cited. For example, increased use of radar and improved navigation techniques may well be alternatives, and conceivably less expensive, to some of the benefits ascribed to improved oceanographic research. These are matters of conjecture; however, it is vitally important to recognize that the widest possible range of alternatives must be considered in calculating benefits. To the extent that the non-oceanographic or non-water-alternatives are available, their costs set limits to the benefits to be ascribed to oceanographic research per se.

In connection with the assumed benefits from weather forecasting, the opportunity cost concept again was ignored by NAS. Even if it is assumed that weather forecasting can be improved to a degree that permits substantial savings of the sort indicated, the benefits do not come free. Some adaptation of current productive methods would be required to make use of the improved forecast, and any change in technology requires that costs be incurred to alter production techniques in the appropriate manner. Obviously, some

9. See, *e.g.*, U.S. Outdoor Recreation Resources Review Commission, *Economic Studies of Outdoor Recreation* (Report No. 24, 1962); Clawson & Knetsch, *Outdoor Recreation Research—Some Concepts and Suggested Areas of Research*, 3 *Natural Resources J.* 250 (1963).

savings would be realized or the change in technology would be economically meaningless, but it is seldom free of associated incremental cost.

In these cases, as in the fishery estimates, there is no conceptual error if the authors intended to include all associated factor costs in the percentage adjustments in column 7 of Table 1. If this is the correct interpretation, however the percentages attributed to oceanographic research—10 to 100%—appear absurdly high.

B. Effects on Market Prices

Another conceptual difficulty of the NAS study involves the impact of additional output on market prices. For some of the benefits estimated, price effects could probably be ignored with impunity. In others, however, it is difficult to see how one could justify the use of current prices for either gross or net benefit estimates where major changes in output relative to existing levels are anticipated. Thus, an increase in fish landings of the magnitude contemplated could not be absorbed at present price levels over the period indicated, unless it is assumed that all of the increased landings displace imports, or that the demand for major groups of fishery products is almost perfectly elastic. Neither assumption seems reasonable. The same criticism applies to some of the calculations of agricultural benefits attributed to more accurate long-range weather forecasting.

C. Scale and Composition of the Research Program

A final conceptual weakness of the NAS study is the failure to consider the appropriate scale and composition of investment in the analysis. If there is no budget constraint, proper application of benefit-cost analysis would require that each separable element of the oceanographic program show potential benefits in excess of costs, and that the level of expenditure in each area be such that marginal net benefits are zero. Even if a budget constraint is operative, the aggregate expenditure on oceanography obviously should be reallocated, since a dollar of additional effort in an area showing a benefit cost ratio of six-to-one would, on any reasonable assumptions, yield a larger addition to net benefits than the amount foregone by cutting back in a field where the ratio is near unity. The benefit-cost ratios shown for the various elements of the oceanographic program suggest only that the scale of the research effort

should be expanded. There is an equally important need to reallocate effort within the program to achieve the largest total net benefit.

III

QUESTIONS OF FACTS AND FIGURES

The NAS study authors are to be commended for developing the estimates of benefits from inevitably scanty data. The study authors claim more than they are able to offer in factual support. The statement, "These estimates are based only on tangible and foreseeable economic results of federally supported oceanographic research,"¹⁰ makes it legitimate to assume that the authors place some confidence in the quantitative estimates provided. Attention has been focused on four areas in which oceanographic research is expected to yield substantial benefits: (1) commercial fisheries; (2) long-range weather forecasting; (3) near-shore sewage disposal; and (4) near-shore recreation.

A. Commercial Fisheries

With respect to commercial fisheries, the issue is simply one of different interpretation of existing facts. The authors of the study seem confident that the United States Government will share in an expanding international fishery to a degree that will provide a major increase in income to American fishermen. The record of the post-war years, with a few notable exceptions, appears to point in the other direction. In general, the American fishing industry has not kept pace with the revolutionary technological changes in fishing vessels and gear that have characterized the post-war years. This reflects in some areas the effects of restrictive union practices (in particular, opposition to having the same men perform fishing and seamen's duties), but in part it simply indicates a comparative advantage to nationals of other major fishing countries. In short, operating costs for American high seas fishing ventures are likely to be substantially higher than those of other nations, and, barring major federal subsidies, it is difficult to see anything in the future that will alter this situation on a broad scale. But of course, even if subsidies are granted, proper benefit-cost calculation would reflect the higher factor cost involved. Thus, it is at least questionable whether

10. National Academy of Sciences, *op. cit. supra* note 5.

America's share in the high seas fisheries will expand or even be maintained except in the few fields such as tuna, where American technology is clearly advanced enough to make the industry competitive on a cost basis.

The general levels of prices and wages in several major competitors—Japan, Germany, and the United Kingdom, for example—have risen more rapidly than in the United States, and higher factor prices, together with the cost effects of depletion on more and more international fishing grounds, may open up new opportunities for the American fleets. For example, it is possible that increasing demand and rising costs might raise prices of frozen fish blocks and fish meal—both are major items in internationally traded fish products—to where American fishermen could participate more actively with only moderate improvements in technology. Nevertheless, it is difficult to envisage a major shift in favor of American high seas fisheries at the present time.

As far as improvement in the American competitive position in the domestic market is concerned, nothing in the NAS study is offered beyond the statement: "If our fishermen, through research and engineering, can recapture the share of the market lost to imports during the past decade and a half by cutting their production costs, an annual market for nearly 800,000 tons of edible fish and a similar amount of industrial fish would be provided."¹¹ The "if" is a very large one. It should be stressed that this opportunity has existed throughout the post-war period, yet it has not been possible for American producers to cut costs and/or develop additional sources of supply that would make them competitive with imports, particularly in the edible fish field.

Moreover, it is by no means clear that technological improvements, arising out of oceanographic research or in better capital equipment, alone would improve the cost position of American producers. Many technological advances and improvements in oceanographic knowledge are likely to be available to all, and the relative position of foreign and American producers may well remain unchanged or even shift further in favor of the former. It is possible that the relative position of American fishermen could be improved even by freely available improvements under some circumstances. Since labor costs tend to be much higher relative to total fishing costs in American operations than in other major fishing operations,

11. *Id.* at 15.

labor-saving developments would favor domestic producers. Also, some types of technological improvements may be specific to particular species found only in areas close to American ports or may be usable only under certain oceanographic conditions characteristic of local waters. In such cases American producers could enjoy an improvement in costs relative to otherwise equally proficient foreign operators. On *a priori* grounds both conditions might be expected to be of some practical importance in individual fisheries. But, in more general terms, it is hard to avoid the conclusion that technological improvements, however desirable on other grounds, will not enable the American fishing industry to make up much ground within ten or fifteen years.

It would appear that the estimate of fifty per cent increase in foreign and domestic fisheries of the United States attributable to oceanographic research may be high. One can only point out that immediate past experience would suggest a more moderate figure, even if the oceanographic effort is increased substantially. In recent decades the major oceanographic effort has been oriented not toward fishery development, but toward heavily exploited stocks, many of which were already in difficulty because of excessive fishing effort. These programs have been most useful in adding to knowledge of the dynamics of economically significant fishery resources, and further effort could expand knowledge of presently unused or underutilized species. But the great barrier to increased economic output from these stocks is not inadequate scientific knowledge, but inability to compete economically with foreign fish producers and domestic suppliers of other protein foods. Even if this is too pessimistic about the long-run cost position of American fishermen, it would appear most unlikely that oceanographic research would be the best (or even a very useful) way to bring about the necessary increases in productivity.¹²

B. Long-Range Weather Forecasting

The benefits that could be derived from improved long-range weather forecasting also seem very optimistic. The NAS report suggests that savings of 2 billion dollars a year might result from improvements made possible by an expanded oceanographic research program. Studies undertaken by the Rand Corporation and

12. We are indebted to D. L. Alverson, of the Bureau of Commercial Fisheries for raising this issue. This does not imply, however, endorsement by Mr. Alverson of the Bureau of the view expressed in this Article.

others suggest that savings would be much smaller than those estimated by NAS.¹³

The benefits to be derived from improved weather forecasting may involve substantial additional costs if the production techniques affected are to be modified to take full advantage of the increased forecasting accuracy. One of the important incremental costs associated with the adaptation to improved weather forecasting would be the additional research required simply to learn how to adapt to it. In part this would be a matter of additional applied research and technology in the industries, particularly agriculture, for which potential savings would exist. In the case of agriculture, and to some extent in others, there would also be a substantial additional burden in the form of extension and educational work required to insure adoption of the more profitable techniques. In an industry characterized by hundreds of thousands of relatively small units, it is hardly realistic to assume that benefits as indirect as those associated with new concepts of weather forecasting and their application would be disseminated fully within one generation.

The authors of the report suggest that improved weather forecasting might reduce the nation's annual bill for flood losses by twenty-five to fifty per cent, or 70 to 140 million dollars a year. Claiming this as a benefit presupposes two questionable assumptions. First, that people would be able to make the necessary adjustments in their activities to take advantage of the improved forecasts, and second, that there are no cheaper ways of achieving this reduction in flood losses. Neither assumption appears to have firm support in the NAS report or in recent studies relating to flood problems. Other evidence suggests upper limits of ten to twenty per cent in the reduction of flood losses through the best possible weather forecasting.¹⁴ Improved forecasting is required, in the main, for small drainage areas—an intractable problem from the viewpoint of long range weather forecasts.

C. Near-Shore Sewage Disposal

The treatment of savings from near-shore sewage disposal aris-

13. See, *e.g.*, Rand Corporation, *Utility of Weather Forecasts to the Raisin Industry* (1961); Demsetz, *Economic Gains from Storm Warnings: Two Florida Case Studies* (1962); Rand Corporation & U.S. Weather Bureau, *The National Research Effort on Improved Weather Description and Prediction for Social and Economic Purposes* (1964).

14. Kates, *Industrial Flood Losses: Damage Estimation in the Lehigh Valley* (Dep't of Geography, Univ. of Chicago, Research Paper No. 98, 1965).

ing out of improved oceanographic knowledge appears faulty. First, the maximum savings that can be attributed to such knowledge are limited by the availability of alternative treatment methods. In addition, waste disposal problems are, to a considerable extent, specific to each area. Moreover, the use of water for disposal is part of a much larger and more complex system of water supply and utilization. An optimal solution to waste disposal problems cannot be specified except in relation to the overall sources and costs of water supply and of alternative methods of handling waste disposal, some of which need not involve water use at all.¹⁵

The possibility of realizing twenty-five per cent savings in construction costs and operating costs is questionable except in conjunction with improved systems analysis of the overall problem of waste disposal within the larger setting of water supply and water quality. If the latter view of the problem is adopted, however, it is no longer possible to attribute one hundred per cent of the savings to oceanographic research alone. Rather, the savings would reflect the overall impact of proper placement of the waste disposal problem in terms of policy determination and administration.

In a more pragmatic vein, there is no evidence that public policy generally is tending toward the admittedly desirable approach of estimating the assimilative capacity of receiving waters in setting waste disposal standards. On the contrary, there seems to be a general drift in the direction of fixed standards of waste removal, at least within states and regions.

D. Near-Shore Recreation

It is difficult to value outdoor recreation, shore-based or other, and the various alternative approaches to the establishment of priorities for research and investment in this increasingly important field of government activity.¹⁶ One can be sympathetic to any author faced with the need to quantify incremental recreation benefits, particularly when coupled with the need to cement the tenuous links between research and results. For those very reasons, however, the magnitude of the benefits projected in the NAS study is highly questionable: (1) it introduces a heavy bias in the final conclusions; (2) it is analytically incorrect; (3) it contains a gross computational error; and, (4) the ten per cent of the annual increase in gross

15. See Kneese, *The Economics of Regional Water Quality Management* (1964).

16. See Clawson & Knetsch, *op. cit. supra* note 9. For analyses of some non-economic bases for evaluation, see Kates, *Comprehensive Resource Plan, 1974: Strategy for Regional Growth* (1966).

expenditures on near-shore recreation attributed to oceanographic research is clearly plucked from thin air.

Analytically, the major error lies in the use of gross expenditures as a measure of net benefits. The computational error involves the use of current total rather than incremental additions to expenditure. As for the choice of ten per cent of whatever benefit one derives as the proportion to be attributed to additional oceanographic research, no supporting evidence is presented. One can only wonder why the rate of growth in near-shore recreation achieved before the expanded oceanographic program got under way should be extrapolated thereafter and designated, even in part, as a result of the additional research effort. Finally, it would appear that some of the benefits gleaned from improved recreation, (better sewage disposal, for example), have already been counted as savings in sewage disposal—which presupposes that receiving water standards for recreational use have been met.

E. Future Costs of Present Research Effort

Scientists capable of independent direction of productive research are also the bulwark of the training programs upon which rests the future supply of scientific personnel at all levels. The elasticity of supply of this group is relatively low, particularly in the short run. Consequently, any major effort to increase basic research activity in a particular field involves some "tradeoff" of increased output in the short-run for a decrease in the flow of scientists and scientific achievement over the longer-run. The situation is illustrated very clearly in the case of oceanography. To the extent that the national oceanographic program is able to sustain the rate of increase of scientific activity planned for the next twenty years, it is likely to place severe restrictions, at least for some period of time, on the ability of its best personnel to participate in the training of doctoral candidates and (probably more important) the recruitment of scientists from other disciplines to meet the needs of the oceanographic field. If expansion of the oceanographic research effort does reduce, even temporarily, the quantity and quality of trained oceanographers forthcoming in future years, the NAS estimates of benefits may be generally overstated.

CONCLUSION

The basic problems of establishing the appropriate level of oceanographic research and its proper allocation among constituent ele-

ments of the program will not be resolved by benefit-cost analysis as undertaken in the NAS study. This area remains one of many in which the economic evaluation of the end products of research and development expenditures cannot yet be done with precision comparable to that achieved in other types of water development. Nevertheless, much can be accomplished by a stronger and analytically sound application of benefit-cost principles to research and development activities in oceanography. The very process of forcing the agencies concerned to isolate and examine the outputs and associated costs resulting from their activities may well lead to an internal reordering of programs in the direction of greater efficiency. There is, after all, more than a trivial number of cases in which benefits from competing programs are roughly equal, and where sensible choices can be made on the basis of costs alone. Similarly, if one program generates larger benefits than others, a basis for rational choice exists if costs of the superior project are as low or lower than those of competing alternatives even though benefits cannot be measured precisely. And the cases where benefits and specific costs associated with them can be measured are numerous and increasing. Some improvement can be realized immediately, but only if the benefit-cost is applied correctly and consistently.

These gains are not without associated dangers. Most of the research in oceanography is done by or financed by federal government agencies. The Bureau of the Budget insistence on a benefit-cost approach to programming may warp agency planning in the direction of mission-oriented as opposed to basic research, and toward applied programs that promise measurable results and away from those where uncertainty, risk, and the identification problem make the measurement of benefits more speculative. Both types of development may lead away from an optimal long-range program. The major output from research in oceanography may, for some time, continue to be basic scientific knowledge—we are still far from the engineering or development stage in most areas where potential economic benefits are most promising. By all means, let us use economic evaluation, wherever possible, to facilitate orderly choice among specific optional projects and as a basis for establishing the proper scale of projects with identifiable economic outputs. We must avoid the real potential danger that easy quantification of results is the primary test of productive government research.