How Much Research?

The educational aspect is crucial in justifying further growth in research.

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The American people, through the national government, have given remarkably strong support for scientific research throughout the period since the second world war. There are very few peace-time activities that have received as strong support as basic research in universities, which was given a 25 percent per year increase in funds each year over the 5-year period 1958–63 after already having grown at a very rapid rate over the preceding decade 1948–58. For the next 3 years, 1963–66, the growth still continued at the relatively high rate of 15 percent per year increase. The total rate of federal expenditure for research in universities was now well over $1 billion per year, and it is not surprising that questions were asked and that congressional committees made special studies of research activities.

Both the Elliot Committee and the Daddario Committee handled their assignments in a most constructive and responsible manner, and their reports were generally favorable. Nevertheless, the question remained unanswered about how much further growth of basic research was really justified. Recently several committees of scientists have struggled with this question. The report, "Basic Research and National Goals," prepared by the Committee on Science and Public Policy of the National Academy of Sciences, is directed primarily to this question.

The requirement most frequently suggested by scientists is one calling for a continued 15 percent annual increase, and this figure is justified on the basis of an 8- to 10- percent annual increase in the number of research students, and a 5- to 7-percent annual increase in cost because of price rises and increased sophistication of instrumentation. But the gross national product and the total federal budget grow at a much slower rate, approximately 6 percent per year. Consequently, it was easy to see that funds for academic research could not continue to grow at 15 percent per year for many more years without becoming an absurd proportion of the federal budget. Since a schedule for a leveling off of the research budget has not been forthcoming from the scientific community, budgetary officials in Congress and in the Executive branch have been forced to make their own decisions, and the result was a reduction to a 10 percent growth from 1966 to the 1967 fiscal year and the prospect of not over a 6 percent growth next year. Even these last figures indicate a strong underlying support for research in view of the budget pressures of the Vietnam War.

I believe it is very important, however, for scientists to continue a discussion among themselves and with governmental leaders in an effort to work out generally acceptable principles for determining how much research. These comments are intended as a contribution to that discussion.

Diminishing Returns

Next let us put aside for a moment the discussion of federal dollars and consider the nature of scientific research as it is today. I believe it is easy to see in the current situation factors supporting a concept of diminishing returns. At least three factors apply here.

First, we see that further growth brings less able people into research. All of the most creative scientists now have little difficulty in finding good positions, and it is quite clear that the contribution of those who are added by further growth in research will be less, per person, then the present average.

Second, there is the enormous increase in published literature which makes communication of really important discoveries more difficult. It is neither feasible nor desirable to prevent the publication of competent but relatively pedestrian research results; nevertheless, the increasing volume of such papers makes it harder for a scientist to learn of the unexpected result which would suggest a new idea for his own work. I am sure that improvements can be made in our publication system, but the fact will remain that the net value of additional research of mediocre quality is diminished by the burden that it places on scientific communications.

A third factor, which is closely related to the second, is the tendency toward over-specialization. As the population of research scientists grows, there is a tendency to split up into narrower fields of specialization. But major discoveries frequently arise from the interaction in an investigator's mind of concepts developed in other fields of science. Excess specialization will decrease the range of science which will be interacting in the minds of creative individuals.

I conclude from these three factors that in many scientific areas the argument for further growth as a means to an increased rate of major discoveries is not very convincing. There are convincing arguments for growth, but these relate to research training, and I shall return to them presently.

Arguments Favoring Science

If we now look outside the research laboratories, we find strong arguments favoring science, but these do not uniformly favor further growth.

Science is an important part of our intellectual heritage; it is a response to our curiosity about nature, about ourselves, and the things we see about us. Consequently, science has an essential position in our education system, and reports of advances in science are of interest to citizens generally. I find it difficult to argue, however, that we need to increase further our research effort in all areas in order to have more discoveries to report to the community generally at a time when the public is interested in only a small fraction of the present research output.

The importance of science and, more

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explicitly, of developments based upon scientific research to economic progress is widely accepted. Certain economic studies indicate that about half of the recent increase of production in this country may be attributed to advance in technology with additions of capital and labor contributing the other half. Since the cost of the additions of capital and labor is much greater than that of the expenditure for advanced education, research, and development, the latter seems very well justified. This is a value to the public that, in my view, does justify further growth in research. In some areas, such as medicine, the value is best discussed as public welfare more broadly than dollar income, but, here, also, I believe additional research can be justified. But if we accept these justifying factors we must accept also certain implications concerning the type of research, its geographical location, and its relationship to education.

Research is more likely to contribute to economic development and public welfare if it is in a field of science related to technology, or to medicine, or agriculture, or is at least relevant to other scientific disciplines from which important practical developments have arisen. Also the nation has a right to expect the benefits of technology to be equally available in all geographical regions, and this is one justification of the demand that advanced education and research be as uniformly distributed over the nation as is feasible.

One of the best methods of encouraging useful developments based upon new scientific discoveries is to bring students who have participated in the scientific work into the development laboratories. In any event, the staff recruits for development, as well as for management of technologically advanced activities, need to be familiar with the latest science and with the nature of research. And the best way to accomplish this is through research activity in the universities in which these recruits receive their most advanced education. Thus, one can build a much stronger case for additional research which is associated with graduate education than for the research alone.

Educational opportunity is given great importance in our society, not only for the welfare of the society generally, but also because we value the individual most of all. In accordance with this principle, we believe that gifted individuals should be able to pursue their education to the most advanced level if they wish. An increasing number of brilliant and creative students are choosing to seek the Ph.D. with the research experience that it implies. This research opportunity should be provided, at least in fields of modest cost, by the necessary expansion of academic research.

We must also recognize those areas of research involving major supporting facilities, such as particle accelerators in the billion-volt range, large telescopes, oceanographic research vessels, and space probes and satellites. These facilities make possible unique experiments that open up whole new areas of science. This nation must maintain a leading role in these fields during the pioneering phase, at least. We cannot afford not to be in the forefront during the exploration of totally new territory. On the other hand, the cost of the work per scientist is so high that it is not reasonable to expect to provide research opportunity for every competent investigator who wishes to work in these fields. Rather, the magnitude of our program should be judged in terms of the importance of the field and the facilities necessary to support a vigorous effort.

"Little Science"

Those who are familiar with recent discussions of these questions will recognize that I have arrived at the definition of "big science" as contrasted with "little science." I am not going to say more about big science; decisions concerning these major national facilities and programs must be made as they are now being made on a case-by-case basis in the government. It is to little science that I now return; the typical unit is a university professor with several graduate students. Instruments are used, but their cost, per year, is small in comparison with the cost for personnel and operating expenses.

Such little science is also carried out in industry and in private and government research institutes, as well as in universities. Indeed, such research may be of great value in support of the pursuit of the industrial or programmatic objectives of such organizations, and should then be supported on that basis. But I have indicated earlier, and I want to emphasize now, that there is much greater public-welfare justification for additional basic research which is associated with education, than for the additional research alone. Thus, I prefer such terms as "research training" or "academic science" to "little science," because I believe the educational aspect is crucial.

Many scientists have argued that every scientist with real research talent should have his program supported if it falls in the range of little science. I maintained this position myself during the years 1949–51 when I was director of research for the U.S. Atomic Energy Commission; at that time it seemed clear that a wider diffusion of research fundamentally relevant to atomic energy was clearly in the national interest. But, the growth in research since 1951 has been enormous, and criteria which were adequate then may be inappropriate now. In fact, it is not clear to me that one can any longer justify support for all competent applicants in the little science area unless their research is an essential part of the training of students in research. But I do believe that one can still justify further growth of the academic science which constitutes Ph.D. level research training because of its relevance to both the development of the talent of individuals and to the progress of technology in terms of both economic growth and public welfare.

Adequate Federal Support

Let us examine more precisely the federal funding that this policy implies. I believe it is possible to have very good academic research in the little science area for a group comprising one professor and four or five students with government support of $50,000 per year. This includes student stipends. I believe it is essential that the federal government continue to carry at least its present proportion of the cost of this type of academic science. There should be, on the average, one Ph.D. per year awarded from this group; hence, we can take $50,000 per Ph.D. as the basis for government funding. This amount is somewhat larger than the estimate of the Westheimer Committee, which was $30,000 per Ph.D. in chemistry. Since approximately 8000 Ph.D.'s are awarded annually in science and engineering, the total expenditure currently required is $400 million per annum if we take the $50,000 estimate.

Let us now recommend that this annual expenditure level of $400 million be increased as required by the growth in numbers of doctoral students and in the cost of research of this type. From this point of departure, an increase of 15 percent per year until 1975 would raise the expenditure level to approximately $1 billion, which would be well justified in my view.

As one looks beyond 1975 it seems very likely that the growth in the number of doctoral students will be slower because the population of the appropriate age group will level off. Also the growth in the proportion of students seeking the Ph.D. may decrease. Hence, I believe one can justify a policy of adequate federal research support of this type, for all qualified doctoral students, as far into the future as is meaningful.

Although this is my primary conclusion, two other matters require attention. One concerns the additional support of research in universities in excess of the level just considered for Ph.D. training. The other concerns the allocation of funds for Ph.D. training among disciplines and among universities, and between institutional as compared to project grants.

The total federal funding for research in universities this year is approximately $1.5 billion, or $1.1 billion more than the $400 million which I attributed to research training for the Ph.D. in little science. This indicates that there is a large amount of intermediate level science in universities which involves substantial instruments, as well as postdoctoral and other professional research personnel in addition to professors and students. Examples include nuclear physics programs involving small cyclotrons or Van de Graaff accelerators. Even a program in chemistry including postdoctoral fellows, and possibly a mass spectrometer, would contribute to this additional cost. There is a large expenditure in universities for medical research, but relatively few Ph.D. degrees arise from this area. I do not intend to discuss this component of cost in detail; I shall only say that it is important; indeed, it is essential to American leadership in science; but I do not believe one can justify its increase in proportion to growth in number of Ph.D. students. Reports such as that of the Westheimer Committee show the importance of these additional costs for better instruments. The need for growth in number of postdoctoral appointments is, in my opinion, an open question which needs prompt study. Certainly the present level of expenditure should be maintained, but I believe it is more important to provide the basic level of research support for additional doctoral students and their professors than it is to increase all of these other categories of research expenditure.

New Core Grants

Finally, I wish to urge a new pattern of grants for part of the basic level of Federal support, which I estimated as $50,000 per Ph.D. Support for the basic costs of any worthwhile but relatively inexpensive research in a given field—for the chemicals, vacuum pumps, oscilloscopes, and similar items—should come through relatively flexible core grants to the university. The size of these grants should be related primarily to the number of Ph.D. degrees awarded in various scientific disciplines.

Project grants for basic academic research were originally intended to provide only the extra support for unusually expensive experiments, but project grants must now cover these basic costs in most laboratories. This is a clumsy method; it is expensive in administrative time and disastrous when a misjudgment denies a good scientist and his students even this basic level of support. The proposed core grants would take over this basic support and allow project grants to resume their original and appropriate role.

A careful study should be made in order to choose the best method for administering the core grants. If they were based simply upon the number of Ph.D. awards in science, a very careful check upon the quality of students and programs would be required to avoid the temptation to lower standards. Also, special consideration would be needed for new programs or for those growing very rapidly. But market forces should be allowed to control the distribution among fields of study and among institutions through student choice influenced by employment opportunities, as well as the intrinsic interest in each subject, and by the attractiveness of each university's program.

Probably the core grants should be allocated primarily on a departmental basis with appropriate consideration of research costs in various fields, but universities should be free to make reasonable adjustments between departments and be able to meet necessary costs outside of, as well as within, departmental budgets.

Funds for student stipends would continue to flow through grants for fellowships or traineeships, as they are presently allocated to universities for award to students. These grants should be increased gradually to replace student stipends in project grants, and then further increased in proportion to the number of Ph.D. degrees granted after appropriate consideration of quality and any other relevant factors.

The new core grants, together with the traineeship grants, would provide the basic cost for research training and would be increased from year to year in proportion to the increase in doctoral theses completed; these funds should not be in competition with the project grants, which would provide additional funds above this minimum level of research training expenditure.

Summary

In conclusion, I believe the components which I have discussed constitute an outline of a sound program for federal support of science in universities, which provides first, a basic minimum of funding proportional to the growth of the research student population, and second, a pattern of grants based upon justified need and individual merit for more costly instruments, postdoctoral appointments, and other factors that allow our best scientists to be more productive. In addition, there is, of course, the array of major national facilities and programs, each judged individually, in fields requiring very costly equipment.

This proposal is based upon my belief that people are more important than machines. While elaborate instruments are important, we should give first priority to those programs which provide the opportunity for an initial experience in research for all our able and creative young minds. We can afford to keep the door open to all these gifted young people; let us be sure to do so.