The Economic Significance of Scientific Research

By R. E. Addison

TO-DAY, scientific research is becoming more and more a part of our modern industrial development, and the economic progress of a nation depends not only on the imaginative application of new scientific discoveries, but also on continual advances in the field of fundamental research which provides the basis for all applied science.

The free interchange of scientific knowledge between the countries of the world has been one of the most important factors contributing to the technological advances of the last hundred years. This was particularly true of the Western Hemisphere, for a great deal of research on this continent has been rooted in scientific discoveries imported from abroad, and the laboratories of Europe have furnished the fundamental principles on which the applied research of the United States as well as Canada has been based. During the war there was little time for pure research and most of the war-time developments were possible because the theories and principles from which they were developed had already been discovered in many different countries, long before the war. In this connection, it is perhaps well to remember that, while Great Britain, the United States, and Canada take credit for the development of the atomic bomb, the basic discoveries were made in Italy and Germany.

Europe's Contribution

The tremendous progress made during the war in the application of already-known theories and principles has left us to-day with a seriously depleted stockpile of basic knowledge in certain crucial fields. For example, further progress in the movement of guided missiles and other objects at a speed faster than sound depends on the deve'opment of an entirely new body of theory which can only be done through fundamental research. There are many other fields where more basic research is needed. But because of the nationalistic tendencies that are developing in the world to-day, international bariers are being placed on the free exchange of scientific knowledge. Every effort should, of course, be made to encourage such exchange and to re-establish conditions conducive to further scientific research and development in Europe. At the same time we should face the fact that the international situation is disturbed at the present time and there are forces at work that make it necessary for each country to depend more and more on its own resources in the field of scientific research and development, and especially with respect to research that is primarily fundamental in character.

Canada's Part

We in Canada are in a particularly vulnerable position. In the past we have received a great deal of our research second hand. For example, in industry, many of our larger companies are branch plants of firms in the United States and the United Kingdom, and therefore benefit from the results of extensive research work carried out by their parent companies. Even when laboratories are maintained here, the work is more along the line of making adjustments to meet local conditions and to solve specific Canadian problems. Undoubtedly for some time to come we will continue to import a great deal of our industrial research in this manner. But during the war, the magnitude of our research program increased enormously and while our scientific contribution was not as great as that of Great Britain or the United States, for the first time in our history our scientists worked on equal

EDITOR'S NOTE—Miss Addison is a member of the Economic Research Branch, Department of Reconstruction and Supply. The views expressed in this article are her own.

terms with scientists from allied countries and helped in the solution of essential problems. We should therefore be looking ahead to the future and preparing for the time when we will be compelled to carry out more of our own research in order to keep up with developments in the international field. The importation of scientific ideas, like the import of patents, is bad for the intellectual development of a country; in time of war, it leaves the country in an extremely vulnerable position; in time of peace, it weakens its competitive position with other nations.

The influence of research on our national welfare and security is increasing steadily. Divorced from practical application research in itself has no direct economic significance, but when the discoveries of science are put to use, then the economic consequences of research are far-reaching. To-day, applied science is permeating all branches of human endeavour. In the field of health, in agriculture, in industry generally, profound changes have taken place as a result of technological progress.

In the industrial field, the effect of scientific and technological research has been primarily to increase output, to develop new products and to introduce new techniques of production, while the application of scientific methods to business practice has often brought about valuable economies and simplifications. Research has also helped to improve the quality and increase the variety of goods manufactured; at the same time, it has raised the efficiency of plants and increased the productivity of labour.

In helping to solve the economic problems facing Canada to-day, research can play an important part. One of the long-range measures by which the Government hopes to balance our trade with the United States is by encouraging manufacturing industries to process more of our primary products and produce articles that we can sell in the dollar areas of the world. With our ready supply of raw materials and cheap electric power, there are many products we should be able to produce efficiently and economically. Research can be helpful in finding the best way to make these goods under Canadian conditions.

Types of Research

Before going on to deal with some of the expenditures made for research in Canada, it might be well to define "research" and distinguish between the different kinds of scientific activity. Research in the broad sense is the search for new knowledge; but some distinction is usually made between different types, although it is difficult to draw any hard and fast line, and every scientist seems to have his own definition. As Julian Huxley has put it "Of course, the categories all overlap and interlock, but they are convenient pigeonholes."[1]

Pure Research

At the top is pure or fundamental research forming the basis for all applied science. It has been defined as investigation directed towards the discovery of previously unknown facts, which give us a general knowledge and understanding of nature and its laws. In its purest form this kind of research is free and untrammelled, without specific practical ends. But in these days of specialization, it is more likely to be directed toward the discovery of fundamental principles in a certain specific field. Applied research, on the other hand, is organized, directed effort to apply known scientific facts or principles to a particular problem. The objective can generally be mapped out in advance for this kind of research and when used for industrial purposes it usually results in the discovery of a new product or process or the solution of a specific problem. The results can often be appraised in monetary terms and the length of time to be allotted to the project can be determined more or less in advance.

1. Huxley, Julian: Scientific Research and Social Needs, London, 1934, p. 253.

Applied Research

But there is also an area of applied research that is broader and more general in its application than the work undertaken by industry for its own uses. It is more fundamental in its approach and aims at the development of a broad field of technology, rather than application for immediate use. Because it is often of a long-term nature and comparatively expensive, such as the work being done in atomic energy or in aeronautics, this type of applied research is more properly considered to fall within the scope of government laboratories, where no attempt is made to assess research in monetary terms. There is, of course, no clear-cut line of demarcation between the different kinds of research, for fundamental research is sometimes done in industrial laboratories and conversely quite immediate practical problems are solved in universities. However, most of our basic research is done in universities and colleges, where it helps in the training of young scientists and, as a co-operative venture, thrives in an atmosphere conducive to the free exchange of ideas.

Background Research

Between pure and applied research lies another type of scientific work—one that has only recently been given a separate category—namely, background research. This has been defined as the systematic observation, collection and analysis of initial data to provide a foundation for either pure or applied research; or to provide the research worker with a fund of standard reference material. This knowledge is used by all sorts of people—engineers, physicians, prospectors, the public at large. A great deal of background research comes within the sphere of government responsibility for it includes surveys and descriptions of basic facts, such as the preparation of accurate geological maps; the determination of physical and chemical constants, the descriptions of species of animals, plants and minerals, the establishment of standards of measurement.

Before the results of research can be used by the manufacturer, the farmer, or the doctor, still further investigation and experimenting must be done. This development work takes place after the initial research at laboratory or comparable level has been completed. It covers work required to develop new products for commercial production or to bring new methods or processes to the point where they can be put into operation. Research and development together add to our fund of new knowledge. Analysis and testing on the other hand, does not, but nevertheless it is an important part of the scientific process. Included under this heading are all the routine laboratory analyses and tests made to ensure that products and processes conform with accepted standards or with government regulations. This type of work, known as plant or quality control in industry, is essential in keeping the quality of a product up to a certain standard or in keeping a plant operating efficiently.

Research Expenditures

In a recent survey on federal research expenditures,[2] information was obtained under the three main categories of scientific activity: research, development, and analysis and testing. In this article however, the analysis is confined to research and development work, as these two fields of scientific endeavour have more direct economic significance.[3] Owing to war-time demands on research, federal expenditures rose to nearly $35 million in 1945, which was seven times the pre-war level. With cessation of hostilities, expenditures dropped to $25 million, but appropriations for 1947 were

2. For details see '*Research and Scientific Activity: Canadian Federal Expenditures*, 1938-1946', Ottawa, 1947, and mimeographed report on *Research and Scientific Activity: Canadian Federal Expenditures*, 1946 *and* 1947.

3. For the last two years, analysis and testing expenditures have amounted to less than 20 per cent of the federal outlay on all scientific work

close to $34 million (see Table 1). During the war, expenditures were, of course, predominantly for military purposes, and a fairly large portion was for capital outlay in connection with the development of atomic energy. This latter work is now directed toward peace-time uses and since 1945 all relevant data have been classified as non-military. In 1947 some $13 million have been allotted for military research and development, while nearly half of the $21 million to be used for peace-time research will be directed toward the development and fuller utilization of our natural resources. Although the total outlay of $34 million for research and development is an increase over the previous year, it is doubtful if actual expenditures will be much higher than in 1946, due to shortages of well-trained personnel and certain types of equipment.

While it is sometimes difficult to compare statistics for different countries because of differences in definition, in methods of collecting data, or in accounting procedures, it might be interesting to make some very general comparisons of 1947 estimates of government expenditures for the United Kingdom and the United States. Calculations have been based on figures in a report of the Select Committee on Estimates[4] for the United Kingdom, and the Steelman Report[5] for the United States. It has been assumed that these figures cover only research and development, and do not include analysis and testing. Of the $400 million dollars Britain is to spend on research and development during this present fiscal year, some $275 million will be spent by the government. This is nearly nine times as much as the Canadian Federal Government has approved for 1947-48. The United Kingdom will be spending thirteen times as much as Canada on research primarily for military purposes (including atomic energy), and more than twice as much as Canada for research to meet the needs of trade and industry, to promote the development of primary industries such as agriculture, fisheries, or forestry, and to improve the health of the nation. As the United States is spending even more than Great Britain on research, American figures are many times greater than those for Canada. According to data published in the Steelman Report, the United States Federal Government expenditures for research and development in 1947 will be about $625 million or over 20 times as high as ours. (In these calculations atomic energy expenditures are not included.) On a per capita basis the British government is spending more than twice as much as our federal government, while the United States government is spending more than one and a half times as much.

4. Third Report from the Select Committee on Estimates, Expenditure on Research and Development.

5. Science and Public Policy, a report to the President.

A National Budget

As more money is being spent on research to-day than ever before, it seems only proper that careful consideration should be given to the manner in which it is spent. One of the best ways of doing this is by drawing up a national research and development budget. The fullest use must be made of funds, personnel, and facilities and the information contained in a national research budget would provide a basis for discussing the adequacies and inadequacies of Canada's research program, and its direction and ends.

In drawing up such a budget there are a number of points to be kept in mind. A proper balance between the different types of research is needed and adequate provision should be made for basic research. Much of our future scientific work will be in highly complex fields such as electronics, aerodynamics or chemistry, and in this type of work, technological advance and basic discovery will be inseparable. The best agency for doing this kind of research is the university (particularly graduate schools); for apart from extending our boundaries of fundamental knowledge,

it helps in the training of scientists, and thrives in the cooperative and academic atmosphere of a university.

Industrial Research

Another point to consider in a national budget is the amount being spent on industrial research, whether undertaken by industry itself or by government agencies. Many of the techniques and devices developed during the war will have a practical application but further research is necessary before they can be used in industry. The cost of research has increased as advances have been made in more complex scientific fields. More elaborate equipment, larger laboratories, more highly trained scientists are needed if an adequate research program is to be undertaken. Apart from a few of our larger industries that have had their origins in scientific research and rely on new discoveries for their future development, the majority of Industries in Canada are made up of a large number of comparatively small firms, unable to finance elaborate research programs. Great Britain has met this situation by the establishment of some 33 research associations in which large and small firms in the same industry cooperate (with some government assistance) on research programe to their mutual benefit. Small industries in the United States are served by an extensive semi-public system of independent laboratories such as the Mellon and Batelle Laboratories. For a small cost they are able to receive a research and scientific service sufficiently comparable to meet their needs with that which larger companies receive from their own laboratories. It is becoming more and more the responsibility of governments to make sure the size and nature of research programs will meet national requirements, particularly in fields where the possibility of direct eonomic returns to individuals or groups is remote.

Military Research

The place of military research and developement in a national research budget is one that receives a good deal of attention at the present time. In the light of developments made during the last war, the importance of research in the interests of national security can hardly be questioned. In view of the greatly expanded military research programs of other countries, Canada's expenditures in this field are likely to remain on a corresponding level for some time to come.

Health Research

Another consideration is that of health. While great progress has been made in the field of mdicine, developments in the biological siences have lagged behind those made in physics and chemistry. But the discovery of nuclear fission and the new uses for radio-active isotopes, have opened up new vistas in the fight against disease. It is hoped that radio-active isotopes will prove as useful as the microscope in extending the frontiers of fundamental knowledge. While no direct financial returns can be expected from research in medicine and the allied sciences, the Canadian economy will benefit in terms of improved health and productivity. Support for medical reseach has not been as extensive in Canada as in other countries and attention should be given to the needs of special research institutes and public health laboratories.

Natural Resources

In a Canadian research budget attention should always be given to research relating to our natural resources. In the past, expenditures have been heavily weighted in favour of agriculture, (and must continue on a high level if we are to keep up with agricultural research in other countries), but the time is fast approaching when serious consideration must be given to the fuller utilization of our other resources. Foreign countries, by means of research, have been able to conserve their resources and use them more economically. Cheaper methods of extraction have been discovered, as well as ways of utilizing so-called "waste

products." In comparison with other expenditures, Canada's outlay on natural resources has been low and a better balance should be reached if research is to be adequate to meet growing industrial requirements.

How Much?

Having pointed out some of the reasons for a national budget on research and development, and some of the considerations that should be made to achieve a balanced program, the next question is, "How much should we spend?" There appears to be little doubt that expenditures should be far beyond those made in the pre-war period. In some fields, the United Kingdom plans to increase their pre-war expenditures tenfold. The United States hopes to double its present budget of $1.1 billion within the next ten years. With costs of discovery steadily increasing, Canada will have to spend even more on research than we did during the war. The Americans have suggested 1 per cent of national income as a minimum target for research expenditures in the physical and biological sciences, including medicine. In view of the need for public support of research, the Federal Government's share has been set at one-half of the total outlay. In Great Britain, where industrial research by private companies is not as extensive as in the States, the Government's share tends to be higher, and in 1947 was over 0.7 per cent of national income (at factor cost). For Canada, the figure might be computed somewhat differently. As Canada's military expenditures are less than those of the United States or the United Kingdom, it is possible that our target for research and development expenditures by all agencies should be about 0.8 per cent of our national income. But as the Federal Government undertakes a proportionately greater share of the research work done in Canada in comparison with the United States, and is more in line with the British pattern, federal expenditures should probably be about two-thirds of the total or about half of one per cent of our national income. On this basis, Canada has fallen far short of a desirable target, even during the war when our expenditures were seven times what they have been in peace-time. In the war period, our expenditures ranged between one-quarter and one-third of one per cent and will not be any higher for 1947, in spite of the expansion of the research program in this year.

In the atomic age in which we are living research must play a vital part in extending our realms of knowledge, in raising our educational and social standards, in continuing the expansion of our economy, and in preserving our national security.

TABLE 1—CANADIAN FEDERAL EXPENDITURES ON RESEARCH AND SCIENTIFIC ACTIVITY, 1938-1947[1]

Year	Research Expenditures	Development Expenditures	Analysis and Testing Expenditures	Total Scientific Expenditures	Research and Development Expenditures as a Percentage of Net National Income at Factor Cost
1938	3,970	917	1,087	5,974	0.12
1939	4,506	1,292	1,335	7,133	0.14
1940	4,712	1,508	1,786	8,006	0.12
1941	5,509	2,129	2,471	10,109	0.12
1942	6,545	4,798	3,146	14,489	0.14
1943	8,146	8,131	3,862	20,139	0.18
1944	9,918	13,163	4,121	27,202	0.24
1945	10,830	23,683	3,423	37,936	0.36
1946	14,994	9,992	5,352	30,338	0.26
1947[2]	22,940	10,715	6,410	40.065	0.31

(1) Fiscal years (corresponding most nearly to calendar years indicated.)
(2) 1947 figures are based on the Estimates approved by Parliament.