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ENGINEERING HISTORY PAPER #85

"Some Aspects of Economic and Rationale for R&D in Canada"

by George T. McColm

(previously published as CSME History Cttee Working Paper 9/1995 – Dec 1995)

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CSME History Committee

WORKING PAPER 9/1995

SOME ASPECTS OF THE ECONOMICS AND RATIONALE FOR RESEARCH AND DEVELOPMENT IN CANADA

by

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December 1995

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Abstract

This paper, by a Canadian economist, is about the economics of research and development in Canada, and was delivered by the author in October 1972 at the 10th Annual Meeting of the Canadian Research Management Association.

It deals not only with the analysis of resource allocations to R&D in economist's terms, but also with the influence of economic considerations on the support for R&D in Canada given by industry and government. Its historical merit lies in being one of the very first in the subject area, in the way in which it links economic theory with the practical outcomes of R&D activities, and in its continuing relevance for the entire period since it was written almost a quarter of a century ago. And, as we all know, R&D can influence the objectives of engineering and the way in which it is practiced in this country.

About the Author

George McColm graduated from McGill University with an Honours B.A. degree, a gold medal and a scholarship. He went on to Harvard for graduate work and studied under Schumpeter and Leontief, among others, and from their ideas developed a strong interest in the economics of science and technology. He then spent several years working on trade analyses at the United Nations Headquarters in New York. Returning to Canada, he joined the staff of the National Research Council in Ottawa in the late 1950's as its research economist and provided data and analytical inputs for the research and education programs that were being developed by NRC and other federal agencies at that time. Later, at the Science Secretariat, he became more involved with Canadian and international statistics and policy developments affecting science and technology, and did similar work for the Ministry of State for Science and Technology. He is now an Ottawa consultant.

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INTRODUCTION

The economics and rationale for research and development can be related in varying degrees and subtle ways to almost every field of study in economics. I must say, also, that I have stayed close to economics in this paper and have not discussed other systematic approaches that can be used for R&D, such as systems analysis or operational research techniques.

Even with economics alone, the magnitude of the task reminds me of the story of Max Planck, of quantum theory fame, who said he started out to be an economist but quit because it was too hard. Bertrand Russell, on hearing the story remarked, 'That's odd. I quit economics because it was too easy!' Perhaps the explanation is that Planck was looking at the real economic world and Russell at the mathematical logic of economics, which was simple.

Economics may be defined as the study of how people choose to use resources to produce and distribute goods and services over time. Although it is the study of the economy, it is sometimes thought of as the economy itself, and the problems of the economy are attributed to economics or economists. The economist is not, as an economist, the grand director of an economy, although he may advise on courses of action and, if in charge of an institution or in a responsible office, use his knowledge of economics in everyday actions, either consciously or as an integral part of his training or intellectual resources.

The economics and rationale for R&D in Canada should be considered here within the context of economics and the role of the economist. In economics, and to the economist, research and development and the innovation process have not always been subjects of interest or of much study until recently. In many books on economics the matter was treated in a summary fashion as an assumption that new knowledge and its application would continue as it had done in the past.

One notable exception was the work of Professor Joseph Schumpeter, who delivered his theory of innovation back in the first decade of this century. In his writings on business cycles, he developed his ideas and gave a prominent role to innovation. He says, and I quote, 'Innovation is the outstanding fact in the history of the capitalist society...it is largely responsible for most of what we would at first attribute to other factors.' Innovation was defined by Schumpeter as 'the setting up of a new production function.' He goes on to say, 'For cases in which innovation is of the technological kind...the physical marginal productivity must, in the absence of innovation, monotonically decline. Innovation breaks off any such 'curve' and replaces it by another...which displays a higher increment of product throughout although, of course, it decreases monotonically.(1)

Underlying this approach is the idea of research and development as a source of innovation and, given the sophisticated nature of today's changes, the skilled craftsman cannot be depended upon as in the past to bring about the innovations we have or expect. This is not to imply that all R&D gives rise to innovation, or that there is a linear relationship.

Professor Sumner Slichter has stated that, 'A significant characteristic of research is the fact that an increase in its output does not tend to reduce the marginal value of its product.'(2) I interpret this statement in terms of Schumpeter's creation of new production functions, each at a higher level of marginal rate of return than the previous one. In effect, innovation implies a concept of a production function for new production functions, with each new one yielding higher levels of return.

Research and development and its results function as highly revolutionary agents in society. Schumpeter, referring to innovation, called it 'the wind of creative destruction.' It is possible that we in Canada, in the past, may have intuitively disliked this destructive wind. It creates employment opportunities, but makes new training programs necessary; it forces institutions and industry to evolve or perish. This is necessary, however, if we are to continue to grow or to create, or to obtain through trade, the resources required to attain the goals of a better society.

Professor Simon Kuznets, who received the Nobel Prize in Economics, has said that, 'while some epochal innovations may be largely technological, the exploitation of the potential growth provided by them usually requires much social invention - changes in arrangements by which people are induced to cooperate and participate in economic activity.'(3) However, it is not our purpose to explore such an interesting byway in this paper.

In effect, I have given in this section a kind of resumé of what I consider to be the fundamental economic rationale for R&D. It has been in terms of the effects of research and development as a source of technological innovation. The message is that it generates innovation in the sense of new production functions that provide for higher level marginal rates of return than previous functions and, in this sense, is unusual.

BASIC RESEARCH

Economic theory suggests that competition in the market will supply less than the optimal amount of basic research. Our society, through grants and contributions, supplements the market, but more economic research is needed as to whether this supplementation is deficient or excessive. On account of this, Professor Harry Johnson suggests that the rationale for the level of allocation of support to basic research will tend to be by rule of thumb.(4) Also, large projects will tend to raise important questions concerning alternative uses of resources, not only for research, but for other purposes. Allocation among major basic research efforts, particularly pure basic research (that is, not directed), raises difficult problems, which have been subject to continuing discussion.

Allocation to the universities, particularly during a period of rapid growth, is conditioned by the need to have, or to encourage, fundamental research in these institutions and the need to attract to them the kind of scientist who can do such research. This aspect was of particular concern in the late 1950's and during the 1960's when our universities were growing rapidly.

Directed basic research, such as that of Bell Laboratories, which resulted in transistors, or that of Du Pont, which resulted in nylon, can be considered part of the allocation of resources by competitive firms in the interest of new products or devices to provide goods and services not attainable through current technology.(5)

The allocation of resources to the basic researcher and, for that matter, any implication of fundamental research management, seems to call to mind the remark made about Hravard men, 'You can always tell a Harvard man, but you can't tell him <u>much</u>.' Although it would be interesting to examine the allocation of resources by successful scientists in basic research, it is doubtful if it would be considered of much value to the researcher. However, even the purest of researchers must intuitively develop the allocation of their resources so as to obtain the maximum net benefit <u>to themselves</u>, their institutions or colleagues.

At the margin, the last unit of cost - be it money, time, or material - should be expected to yield a return equal to the cost in the eyes of the scientist. The problem is somewhat compounded in that the returns and probability of returns may be similar to the economics of buying a sweepstake ticket. The effort, nonetheless, contributes to our culture and the 'payoffs' have been large.

APPLIED RESEARCH AND DEVELOPMENT

Applied research and development may be considered as an investment that is expected to have a 'payoff' in the future from some new product, process or service. As an investment, it can be evaluated as any other investment and against competing areas of resources or capital. However, for accounting purposes it is often treated as a current expenditure, and also for tax incentives. It is usually treated as current expenditure by government or educational institutions. Nevertheless, although accounting practices or tax laws may not consider it as a capital expenditure, the evaluation made - either intuitively, or fuzzily, or with the most sophisticated analysis - is similar to that made for capital investment. Cost-benefit or cost-effectiveness analyses, for example, will treat R&D expenditures as a capital investment. This means that investment theory can be applied to R&D. The problem is that the next unit of investment may be for the next budget period or program and, as such, treated as a current cost and compared to other current costs.

Furthermore, the return from such research is hard to measure since only part is capturable through patents, design or know-how and part is of general benefit and cannot be captured by the private individual or institution. These may be referred to as externalities, in this instance, negative or a loss.

However, one must consider that by doing research and development one has the capacity to capture or obtain the benefits of the research done by others (their negative externalities are positive to other researchers) through licencing or through information available but not accessible without a research capacity.

Evaluation can be made, and usually is, of the benefits derived from either a specific research project or, more generally, a research program, since some projects may result in negative findings. The company or individual is interested in the benefits obtained from such activity. However, from the point of view of any individual or company, benefits from R&D must be, in the stringent sense, at least equal to the benefits that can be obtained from alternative courses of action or use of resources.

One hears about measures of benefits in terms of jobs created (forgetting, of course, about old skills made obsolescent), and about value added. <u>But the benefit that is most important to allocation is the net benefit to the individual or institution, and particularly to a corporation</u>. A great deal of volume without a high profit margin is described by Frank Carey, President of IBM, as abhorrent 'wheel-spinning.'(6) This position is valid in an economic sense, since it does indicate that resources are allocated in an optimal way when net benefit or profit is maximized. It does raise the problem of R&D administration, which is not common to other areas of trade-offs among conflicting goals. One does not invest time, money or resources in an activity that returns less than an equally appropriate, but different, activity to the attainment of one's goals.

From the point of view of society, some of the benefits may not be capturable by the entity undertaking the activity. R&D going into aircraft, for example, may result in a return based on the sale of airplanes; but a resulting major innovation may be in transportation and the benefits in the expanded potential use of scarce managerial, scientific and professional personnel, whether in government, industry, the universities or elsewhere. The abilities of highly skilled people can be widely expanded. The area of application of these abilities may be expanded from a few miles to a few thousand miles through better transportation. Significant contributions may be made to productivity. Instead of managing one small undertaking, these skills may be used to manage a number of enterprises over a large area. Europe is now an overnight journey, not a week away.

The total return, then, from considering the R&D process in aircraft only, may be inadequate to the aircraft manufacturer, although certainly highly essential for decision-making by firms concerned with the best use of resources in the aircraft manufacturing industry. The effect of the external benefit to the economy may not be measured or measurable.

Perhaps support of this industry is based on the positive externalities that become available to society. My concern here is how we account for the steady increase in productivity in the total economy when some of our measures account for only a part of the total contribution of R&D.

Measurement of benefits from research are usually related directly to results of R&D activity. Indirect, but important, results are obtained also through R&D by being able to detect and use the results of new discoveries made in other institutions and countries. In other words, research and development is a way of obtaining ideas for exploitation from other sources. It is an important part of the technological transfer process. From the point of view of research management, this means an awareness of that which is <u>not</u> invented here and a willingness and determination to use ideas developed elsewhere. For Canada, this is of paramount importance. <u>We do less than three percent of all R&D done in OECD countries and, even if we tripled our resources on it, we would still be dependent or interdependent - whether we like it or not</u>. Only five percent of patents taken out in Canada are held by residents.

We need not feel too badly about this. E.I. Du Pont de Nemours & Company, which most will agree is a successful company in product innovation, had the following experience. Of twenty-five important product and process innovations (accounting for forty-five percent of total sales), only ten were based on inventions of Du Pont scientists.(7) I recall reading that the head of research at Du Pont said that one of the important benefits from doing research was the ability to detect and licence new discoveries made elsewhere. This was of particular importance to Du Pont when you consider that some of the new products the Company obtained from elsewhere included viscose rayon, cellophane, dacron, tetraethyl lead, synthetic ammonia, freon refrigerants, and Dulux finishes.

The experience of Du Pont leads to the use of international trade theory and, within trade theory, the theory of comparative costs or comparative advantage, which explains why it pays to specialize.(8) This specialization pays even if one institution or country has an absolute superiority in all branches of production, as long as the relative efficiency is greater in one commodity than in another.

Freon and tetraethyl lead were discovered by General Motors but licenced to Du Pont since it paid GM to concentrate on its own product lines and Du Pont on chemicals. I could go further into this, but feel that it is enough at present to say that this kind of economic analysis represents the allocation mechanisms that do occur and the relevant economic theory supplies some understanding of the economic phenomena. It may not be unimportant that at the time of the above decisions, Du Pont owned a large share of General Motors stock.

ECONOMICS OF R&D IN INDUSTRIAL STRATEGY

What I have just said leads into the economics of R&D relevant to industrial strategy. Whatever the strategy, taking it or industrial policy as given, the economics relevant to R&D can be applied and used to contribute to the decision-making by R&D management.

If, for example, trade and tariff policy should result in lower tariff protection, international trade theory should provide some guidance on the kind of research strategy necessary to maintain a competitive position by developing products and services that can be sold at home and abroad. This will be of considerable importance to firms built to exploit a previously protected market. Such firms will have to develop and use management, including research management, in order to attain or maintain success. The decisions of such management will be conditioned to optimize Canadian resources and will require that management be well aware of those factors that can give Canada a competitive advantage.

Knowledge of fiscal and monetary policy is necessary to anticipate the forces leading to expansion or contraction of the economy. The interpretation of the implications of changes in these policies is of particular importance when one considers R&D as an investment. The annual current expenditure review of that which is an investment, although in knowledge or intellectual capital, has to be considered.

Competition policy and the effects of it have been very important for Canada. Decisions in the United States have led to significant changes in research in this country. Laboratories have been established here, for example, to provide for greater competition in telephone equipment and services. Chemical research was affected by a U.S. court decision on cooperation between C.I.L. and Du Pont. Economic analysis has indicated that very large corporations are less likely to be successful in R&D than smaller ones. However, the optimum size of a corporation for successful R&D is still in doubt.

Patents and patent policy have been the subject of much economic analysis and study. The benefits and costs are difficult to evaluate. Leontief, another Harvard professor, has succinctly stated some of the pros and cons for a patent, copyright and licencing system. It provides quantity dimensions for that which objectively has none, and makes it possible for enterprises to engage in ideas and new knowledge for a profit. It cannot, however, go far enough - and the range of practical applications that are patentable is limited.

On the other hand, the resulting restriction on the use of new ideas inevitably leads to retardation of technological progress and economic loss. Leontief points out the example of productivity increase in agriculture brought about by absolutely free access to a steady flow of advanced technical ideas financed by federal funds. He does not explicitly suggest a remedy.

Leontief's remarks were made in the introduction to a book by Leonard S. Silk, <u>The Research Revolution</u>, which provides - in a discussion of transistors - an interesting study of the effects of access at a nominal cost to both patents and know-how.(9) Bell obtained its benefit from the rapid growth of the transistor industry, which provided inexpensive but reliable transistors. Bell's prime interest was in the use of transistors and not in their production. Xerox, on the other hand, maintained its patents and know-how and is undoubtedly successful. I wonder what the effect would have been if their technology had been freely available. Would we have been smothered in an avalanche of paper?

These few examples indicate how economic analysis may be used in considering the implications of industrial or economic policy for research and development, and also for innovation. Some general comments might be appropriate on a problem that may have bothered some research managers, namely, the apparent stability for a number of years of secondary (or manufacturing) industry's share of GDP and, more recently, the decline of this share. The matter is somewhat similar to that which concerned the Physiocrats of 1750, who believed that all wealth came from agriculture, when eighty percent or more of production was attributed to this sector. Even in the last forty years (1930-1970), the decline in the size of the agricultural sector has been startling, while productivity has been high. Perhaps we can apply some arguments from the Physiocrats to manufacturing and develop a new economic school of 'Manufacturocrats.' Perhaps we can find some greater understanding of that which may be happening.

The change in the relative importance of the sectors of the economy requires careful consideration of its implications for R&D. The future customer for products may be a service institution buying products from other institutions, such as manufacturing firms, in order to provide services to individuals. The patient (or customer) may receive the services of a clinic or hospital and not buy medical goods and supplies. Many services, such as the cleaning of clothes or apartments, may be contracted to a service industry. The service sector is an outgrowth of specialization, which first developed in the manufacturing sector. Nowadays, we even have our food prepared in the factory - TV dinners, bread, etc. The nature of the products needed in the future will undoubtedly be changed by this development of the service industries.

SOME USES OF ECONOMICS OR ECONOMISTS IN GOVERNMENT R&D

I would like to indicate now, from experience in government, some areas where economic analysis may help.

When the Science Council was preparing its report, Towards a Science Policy for Canada, I would like to think that the work was aided by Jan Tinbergen's book, On the Theory of Economic Policy.(10) The economic model presented in this work was used by Professor Lithwick of Carleton University to provide a conceptual framework for goals, their economic significance, and the relationship of R&D to their attainment. This framework was important in conceptualizing the inter-relationship of science to society. The data to do hard economic analysis with this model was not available, but I felt that the concepts developed were of some use in the staff work for the Council.

The economics or rationale of R&D incentives by government may be considered in a number of ways. One important way is paying for externalities, that is, for the knowledge or ideas generated by a firm's research and development activity, which it cannot capture, but which is of benefit to others. Perhaps, as in the production of aircraft, the benefits are available at the service industry level, or at the individual level, and may benefit a large sector of the economy.

A more specific rationale is to lower the cost of the next unit (or marginal unit) of research and development, whether it is a new research facility, additional workers, or the expansion of old facilities. The next unit of investment, that is the marginal unit, has its cost cut either by a tax incentive or by paying through grants the salary of a researcher for a number of years, or by paying part, say half, of the cost of the program. The idea here is to make investment in R&D attractive, but at the same time to ensure that it will be evaluated by industrial management since it will cost something - although not as much as some other activities. Grant programs are, of course, evaluated for effectiveness and benefit.

If the total amount were paid under these incentive schemes, plus a profit, then the R&D would have to be of interest to - and evaluated by - the agency funding it. In fact, one could visualize research being done, not necessarily in the firm's interest, but as a product of a research industry. This, of course, can be the case when the work is done for defence or for another government purpose. Benefits through 'fall-out' can accrue to the firm, such as is intended by the 'Make-and-Buy' policy, but the evaluation is not necessarily in terms of the firm's investment in research for its own use.

The federal incentive programs in Canada tend to be related to annual budgets, although they will be financed over a number of years. This may tend to provide for the evaluation of each year's expenditures, as mentioned before, rather than the accumulation of past expenditures and the evaluation of potential future returns.

Some arguments have been presented for government financing the total cost of certain programs that are of interest to a firm. Perhaps, using Leontief's idea concerning agriculture, this might be useful, particularly if the results are freely available to all. The pattern of development in Western countries makes the approach to agriculture unlikely for manufacturing.

I have not very much information on the role of economists in research facilities in Canada. Economists have been employed with some research organizations for some time. In the defence sector, Colonel Goforth, who was an economist and Director of Staff Studies (Weapons), employed economists as well as scientists to evaluate new war equipment during World War II. He was also concerned with the setting up of the Defence Research Board after the War. I worked under him and did a background study on research in Canada and elsewhere at that time.

Among matters I worked on while with the National Research Council was the evaluation of the need for the support of scientists in the universities. Another task was obtaining more data on R&D in Canada.

The Glassco Royal Commission's Special Area Study of Scientific R&D had the benefit of economic input in addition to that for the Commission itself. The Science Secretariat and the Science Council have both used economists in their work. The new Ministry of State for Science and Technology has a number of social scientists and economists. (11) I am sure that others can be found working closely with scientists in government and elsewhere. However, I think that the role of the economist in a science organization is similar to that of a scientist in an economic organization, such as a bank. I, for my part, would like to see a recognized scientist or engineer as a vice-president of a bank that loaned venture capital to science-based industries and, of course, more economists and economics in R&D institutions.

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(6) FORTUNE Magazine, March 1972, page 149.

(7) Willard F. Mueller, The Origins of the Basic Inventions Underlying du Pont's Major Product and Process Innovations 1920-1950, from a Conference on The Rate and Direction of Incentive Activity, National Bureau of Economic Research, Princeton University Press, Princeton, 1962.

(8) With a given amount of labour and capital, Country (or producer) A produces 100 units of X and 60 units of Y (ratio 5/3); Country B produces 50 units of X and 40 units of Y (ratio 5/4). It pays A to concentrate on X and B on Y.

(9) Silk, op. cit.

(10) Jan Tinbergen, On the Theory of Economic Policy, North Holland Publishing Company, Amsterdam, 1966.

(11) Since this paper was written, the Science Secretariat, the Science Council of Canada and the Ministry of State for Science and Technology have all disappeared.

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