INNOVATIONS AND ECONOMIC DEVELOPMENT— THE CANADIAN CASE

BY O. J. FIRESTONE

University of Ottawa

This paper assesses the role of inventive and innovational activity in the growth process of Canada, a country which relies overwhelmingly, some 90 per cent, on the importation of technological advances and operational know-how from abroad. Canada has prospered under this arrangement but at a price. With technology came foreign capital, foreign management and substantial foreign control. To lessen Canada's dependence on foreign know-how, this country has embarked on an expanded R & D programme. But the pay-off from these efforts has been less than expected. To throw a light on the subject, the results of two new surveys are presented: one a sample survey of patents granted, the other an interview survey of large corporations. Questions examined include sources of know-how and technological advances, utilization of inventions and abandonment of innovations, R & D and innovations, domestic and foreign innovations, and the profitability of innovations. Aggregative assessment is supplemented by disaggregative analysis using cross-section and industry data.

INTRODUCTION

Canada shares with many other smaller industrialized countries the experience of relying heavily on innovational know-how from abroad. How is this technological progress incorporated into the economic growth process and at what costs? Canadian R & D expenditures and patent data are used in an effort to quantify some of the economic implications. This paper covers for Canada, in part, some of the areas which Jacob Schmookler has covered for the United States.[1]

Specific questions examined include: (1) Where does technological knowledge come from and how readily is it applied in Canada? (2) To what extent are inventions utilized? (3) To what extent are innovations abandoned? (4) To what extent does R & D contribute to the creation of inventions? (5) What are some of the economic consequences of Canada's great reliance on foreign innovational activity? (6) Do cross-section data indicate a relationship between innovation and profitability?

In this paper, innovational change is measured by using patent data. There are a number of inadequacies in such data, including:[2]

[1] *Invention and Economic Growth*, by Jacob Schmookler, Harvard University Press, Cambridge, Mass., 1966.

[2] For comments on the subject see "Inventive Activity: Problems of Definition and Measurement", by Simon Kuznets, and "Some Difficulties in Measuring Inventive Activity", by Barkev S. Sanders, in *The Rate and Direction of Inventive Activity*, R. R. Nelson, ed., Princeton University Press, Princeton, 1962. Other assessments include *The Sociology of Invention*, by S. C. Gilfillan, Follett Publishing Co., Chicago, 1935; "The Course of Invention", by Barkev S. Sanders, *Journal of Patent Office Society*, October 1936; and "The Patent Utilization Study", by Joseph Rossman and Barkev S. Sanders, *The Patent, Trademark, and Copyright Journal*, June 1957. The leading authority is Jacob Schmookler who has written extensively on the subject, including "The Interpretation of Patent Statistics", *Journal of the Patent Office Society*, February 1950; "The Utility of Patent Statistics", same journal, June 1953; "Patent Application Statistics as an Index of Inventive Activity", same journal, August 1953; "The Level of Inventive Activity", *Review of Economics and Statistics*, May 1954; and *Invention and Economic Growth*, *op. cit.* particularly pp. 20–24.

1. Patent statistics reflect the number of inventions for which patents have been applied for. Some inventions are not patentable under the law,[3] while others, though patentable, are not patented by their owners for numerous reasons. One example would be the entrepreneur's judgment that treating the invention as a trade secret would be more profitable than divulging the information to the public,[4] even though the inventor may obtain a limited monopoly under the Patent Act to appropriate the exclusive benefits for himself by either working the invention, selling it, or licensing it to others.[5]

2. Patent statistics indicating the number of inventions do not provide any information on the quality and economic viability of the invention. Unless obtained through special surveys, patent statistics do not indicate whether the inventions are worked or not, and if in fact they are worked, whether they have considerable or little value in the market place. A U.S. study suggests a range of commercial values of inventions utilized, placed by the patentees themselves at between $5,000 and $1,000,000 with the mean value of $250,000. For unused inventions, the corresponding figures are $500, $50,000 and $17,000.[6]

3. Patented inventions become innovations only when they are put to use. Utilization rates differ from country to country over time. In the United States, the ratio is about 1 to 2, in Canada 1 to 6 (as explained later) and in the United Kingdom about 1 to 3.[7] For the United States, the comment is offered that "patent statistics will tend to reflect a declining proportion of inventive activity as we approach the present."[8] This implies that as one goes back in time, patent statistics become a more meaningful indicator of inventive activity. Some cross-section data from the statistical sample survey, in conjunction with patents granted over time, support this claim.[9]

This paper utilizes some of the results of two surveys. One is a statistical sample survey of the owners or assignees of 5,709 patents granted in Canada in 1957, 1960 and 1963[10] conducted in 1968 and 1969. The other is an in-depth interview survey of senior executives and patent specialists of 15 companies operating in Canada, large domestic and foreign-owned corporations, employing 130,000 persons, with gross sales of $4.7 billion and a total portfolio of over 30,000 patents, representing a coverage of between 10 per cent and 13 per cent

[3]Patent laws differ from country to country.

[4]The trade secret applies not to the final product which comes to the market, but to the process and the technique utilized in producing it.

[5]There is also the point that there may be differences of views of what is patentable and what is not, as between the patent applicant and the Patent Office. Hence there would be a difference in the number of patent applications filed and the number of patents granted. Other reasons include patent applicants deciding not to proceed with the patenting after filing the application, and administrative delays.

[6]*Ibid.*, p. 54.

[7]*Report* of the Committee on the British Patent System presented to Parliament by the President of the Board of Trade, London, July 1970, p. 14.

[8]*Invention and Economic Growth, op. cit.*, p. 25.

[9]The proportion of patents granted to individual inventors to total declined from 26 per cent in 1953 to about 10 per cent in 1970. There is some indication that early in the 20th century over 90 per cent of patents issued went to individual inventors and less than 10 per cent to corporations. (See *Report on Intellectual and Industrial Property*, Economic Council of Canada, Information Canada, Ottawa 1971, p. 47.) See also *Economic Implications of Patents*, by O. J. Firestone, University of Ottawa Press, Ottawa, 1971, Chapter 6.

[10]About 10 per cent of total patents granted.

of Canadian manufacturing. The two surveys were undertaken by the author at the request and with the assistance of the Economic Council of Canada,[11] with the details published in the author's study.[12] The two Canadian surveys are somewhat similar in nature to the survey of patent practices of British industry and their economic effects, undertaken at Cambridge University under the direction of Aubrey Silberston.

Putting it broadly, patent statistics and data on R & D expenditures are not as useful indicators of inventive and innovational activity for Canada as they are for the United States and the United Kingdom. As to patent statistics, one of the main reasons is that the proportion of patents utilized in Canada is considerably less than that indicated for the other two countries. As to R & D expenditure data, Canada depends to a much greater extent than the United States and the United Kingdom on the importation of technological knowledge. The usefulness of both sets of data for interpretative analysis can be enhanced if they are examined in conjunction with cross-section data and qualitative information, such as was obtained for Canada from the two special surveys mentioned above and other supplementary data such as royalty payments made for technological know-how in Canada and abroad, as elaborated on later.

Sources of Know-How and Technological Advances

During all their history, Canadians have relied to a major extent for their industrial development on know-how and technological advances from abroad. In 1874, some 42 per cent of all patents granted went to Canadian residents. The proportion declined to 16 per cent in 1900, 8 per cent in 1950 and to 5 percent in 1970.

During the last century, the main foreign source has always been the United States. The United Kingdom was the second most important source during the late 19th century, with her place being taken by third countries at the turn of the century. Broadly speaking, in the first half of the 20th century, the role of the United States as a source of technological knowledge decreased somewhat, that of the United Kingdom rose, while that of third countries varied little. In the last two decades, however, the situation changed dramatically as Canada turned increasingly to the industrialized countries of Western Europe and to Japan for innovational knowledge[13] (see below). Still, in the 1970's, the United States remained the major source of foreign inventive ideas flowing to Canada, with close to 70 per cent of patents granted going to U.S. residents, mainly major national and multi-national corporations.

[11] *Report on Intellectual and Industrial Property, op. cit.*, particularly Chapter 4.

[12] *Economic Implications of Patents, op. cit.*, particularly Appendix A and B.

[13] Examples of inventions from abroad used in Canada include the Polaroid camera, the Xerox process, and transistors (United States); jet engines and crease resistant fabrics (United Kingdom); cellophane (France); diesel engines (Germany); and DDT (Switzerland). Examples of inventions that Canada gave the world include insulin, the cobalt bomb, the skidoo, the powerful explosive RDX and calcium carbide which led to the founding of the giant Union Carbide Corporation in the United States and the Shawinigan Chemical Company in Canada. Many inventions made in Canada had to be developed abroad with Canada importing such articles from foreign producers. (See *Ideas in Exile*, by J. J. Brown, McClelland & Stewart Ltd., Toronto, 1967).

Per Cent of Patents Granted to Non-Resident Inventors[14]

	United States	United Kingdom	Other Countries
1874	92.2	6.0	1.8
1900	84.3	6.7	9.0
1950	80.6	11.7	7.8
1970	69.6	7.6	22.8

The time lag of technical knowledge flowing from abroad to Canada may be considerable. It is likely to be less if the flow of the information is from a foreign company to its subsidiary in Canada. But it may take a good deal more time in other cases as foreign firms consider the best way of utilizing their invention in Canada. Should they obtain a patent? Should they export the patented product to Canada? Should they seek a licensee to produce the article in Canada? Should they produce the commodity themselves either on their own or through an associated company?

The statistical sample survey indicated that 87 per cent of all inventions patented in Canada in 1963 were worked abroad anywhere from 1 to 12 years prior to the date of the Canadian patent grant, on an average about 4 years.[15] In many instances, patented inventions were also worked in Canada prior to a patent grant, though to a lesser extent.[16]

To the extent that foriegn firms patented their inventions in Canada with a view to having the market served by the invention to themselves without actually innovating in Canada—defensive patenting—the Canadian patent system appeared to be ineffectual to ensure the utilization of inventive ideas flowing into Canada from abroad.

Observed the Economic Council of Canada: "After the four-year delay from the making available of the technology to the world through actual working abroad to the issuance of a Canadian patent, one finds another three-year delay set by the conditions of the International Convention followed by an additional period of about two years before a licence has been processed. Thus even successful applicants under the present provisions can only expect to get access to technology almost nine years old. In today's rapidly changing world these methods or products may well be obsolete. . . . Canada's patent system takes on a role largely of market protection rather than a role of providing incentives to domestic innovation."[17] (Reference is to compulsory licensing.)

Another study[18] supports the contention that as Canada becomes more industrialized she is becoming even more dependent on technology originating abroad. Since over half of Canadian manufacturing industries are foreign controlled, and since most of the innovative effort is concentrated in this sector,[19]

[14]Based on data by courtesy of Patent and Copyright Office, Department of Consumer and Corporate Affairs.

[15]See Table 8, Appendix A, *Economic Implications of Patents, op. cit.*,

[16]See Table 7, *ibid.*

[17]*Report on Intellectual and Industrial Property, op. cit.*, pp. 78 and 79.

[18]*Foreign Owned Subsidiaries in Canada* 1964–1967, Department of Industry, Trade and Commerce, Ottawa, 1970, p. 122.

[19]In 1963, some 90 per cent of all patents granted covered inventions for use in manufacturing. (See Table 19, Appendix A, *Economic Implications of Patents, op. cit.*)

the following data relating to innovative efforts of foreign controlled companies have a bearing.

1. In 1967, about 70 per cent of all royalties for technological know-how paid by these countries went abroad, with 30 per cent spent in Canada.

2. Dependence on foreign know-how was accelerating as royalty payments abroad increased at more than twice the rate of royalty payments and R & D expenditures made in Canada.

3. Over 90 per cent of royalty payments went to the United States, indicating the great dependence of Canada on innovational activity originating in this country.

4. About half of the royalty payments going abroad in increasing amounts from Canada are paid for by the Canadian taxpayer, since they represent a deductible expense. These royalty payments help finance R & D work abroad. This produces more inventions, which then again are patented in Canada, leading to further royalty payments. This practice seems to make good economic sense but the question that is now being raised is: What can Canada do to break out of this continuously widening circle of dependence on foreign technological know-how?

Looking at this and other evidence, the Economic Council of Canada concluded: "As a means of encouraging industrial innovation in Canada, whether based on domestic inventions or on foreign inventions, plus rapid 'technological transfer' into Canada, the existing patent system has not been an outstanding success. . . . Looking at patents as an international system, there is a presumption that we are carrying too large a proportion of the costs of the system in relation to the proportion of the benefits that we receive."[20]

The Canadian patent data examined later indicate that the major part of inventive activity took place in four industries: chemical products, electrical products, transportation equipment and machinery industry. In 1963, these four industries obtained 66 per cent of patents granted.[21]

In 1967, these four industries were responsible for 28 per cent of the gross value of output. Excluding the machinery industry for which no historial data are available, the proportion is 24 per cent. Roughly comparable proportions for the three remaining industries are 1950, 18 per cent, 1900, 12 per cent, and 1870, 7 per cent.[22]

Capital expenditures made in these four industries in 1970 amounted to $694 million or 22 per cent of the total of all manufacturing. In 1960, the proportion was 18 per cent. Over this decade, capital expenditures in these four technological lead industries rose by 230 per cent and those of all other manufacturing industries by 155 per cent.[23]

The data confirm the hypothesis advanced earlier that industries with the greatest emphasis on innovational activity have also been among the most

[20] *Report on Intellectual and Industrial Property*, *op. cit.*, p. 81.

[21] See Table 19, Appendix A, *Economic Implications of Patents*, *op. cit.*

[22] The data for 1967 are from 1967 *Annual Census of Manufactures*, Dominion Bureau of Statistics, Ottawa, November, 1969. Other data are from *Historical Statistics of Canada*, M. C. Urquhart, and K. A. Buckley, eds., Cambridge University Press, Toronto, 1965, pp. 463 471, 472, and 474.

[23] Data from *Private and Public Investment Outlook in Canada*, 1971, Department of Industry, Trade and Commerce, Ottawa, 1971, and earlier issues.

rapidly growing sectors of the economy. They also lead in terms of growth rates of capital expenditures made.

The industrial classification of patent data differs among the three countries. In the United Kingdom, a roughly comparable proportion for sectors described as engineering, electrical and chemical industries is 63 per cent.[24] For the United States the proportion covering chemical products, machinery, electrical equipment, and communication and transportation works out at 72 per cent.[25]

Utilization of Inventions

Schmookler makes four claims in relation to the utilization of patented inventions in the United States that can be tested against results of the two Canadian surveys:

1. Patent statistics for certain periods are a useful indicator of inventive output since according to U.S. experience about half of all patented inventions are put to commercial use.[26]
2. The rate of commercial exploitation over time is rising.[27]
3. Patented inventions "owned by small firms are more frequently used than are those owned by large firms".[28]
4. There is an increasing tendency to rely less on patenting in more recent times than previously.[29]

Dealing with the first point the proportion of patented inventions utilized in the United States ranged between 44 per cent and 57 per cent, varying by industry and type of utilization.[30] The Canadian statistical sample survey showed that about half of all the inventions patented in Canada *and* abroad were put to commercial use abroad. This however, was not the case as far as utilization rates of patented inventions *in* Canada are concerned, where the proportion was only 15 per cent. Hence the statistical sample survey supports the validity of the claims made by Schmookler for the United States but does not do so for Canada.[31] For Canada, the utilization ratio is about one in six, in the United States one in two.[32] Hence Canadian patent statistics are a much less

[24]The data relate to 1960. (See *The British Patent System*, by Klaus Boehm in collaboration with Aubrey Silberston, Cambridge University Press, Cambridge, 1967, pp. 145 and 176.)

[25]The data relate to 1959. (See *Invention and Economic Growth*, *op. cit.*, p. 169.)

[26]*Ibid.*, p. 50.

[27]"There is a strong possibility . . . that the proportion used commercially has roughly doubled in the past half century." (*Ibid.*, pp. 55 and 56.)

[28]*Ibid.*, p. 55.

[29]Hence, "patent statistics will tend to reflect a declining proportion of inventive activity as we approach the present." (*Ibid.*, p. 25.)

[30]Reference is also made to a survey conducted by Frederick M. Sherer, et alia, which indicated a 54 per cent commercial utilization rate. (See *Patents and the Corporation*, privately published, Boston, 1958, Chapter XII.)

[31]About 93 per cent of all inventions patented in Canada are also patented abroad, usually in the United States and to a somewhat lesser extent in the United Kingdom, France, Germany Italy and Japan (based on data excluding "not stated" as per Table 2, Appendix A, *Economic Implications of Patents*, *op. cit.*)

[32]The difference between the Canadian and United States patent utilization rates may be less than is indicated above because the term "used" in the American survey may cover a broader area than the phrase "worked" in the Canadian survey.

reliable indicator of "inventive output" than are U.S. data. The question arises: What are some of the reasons for the difference?

1. Market scale. The United States market is close to ten times the size of the Canadian market in terms of population and about twelve times in terms of purchasing power.[33] Since costs of introducing innovations into the productive process are frequently quite substantial, market size differentials contribute to higher development expenditures per unit in Canada than in the United States.

2. Tariffs. Even though the Canadian tariff system offers secondary industries a fairly high level of "effective" protection,[34] Canada is a major importer of manufactured products, particularly machinery and equipment. Some of these imported products have the added protection of patents granted in Canada, discouraging competitors from entering the field notwithstanding the existence of compulsory licensing provisions under the Patent Act.

3. Firm size. Most American companies are larger in size and financially stronger than corresponding Canadian firms and thus are better able to shoulder the costs and risks of innovating.

4. Antitrust. "Antitrust policies . . . and a political atmosphere on the whole hostile to patents since the late 1930's."[35] Anti-combines policies, decisions of judiciary and public attitudes were not as inimical to patent protection in Canada as they were in the United States. Hence the pressure to utilize patents in Canada was less than that in the United States and this suggests the possibility of greater use of "defensive" patenting[36] in the former than in the latter country.

On the second point, the Canadian statistical sample survey offers only slight support since the time interval for which comparable data are available covers only 6 years. The proportion of inventions patented in Canada *and* abroad, and worked abroad, mainly in the United States, rose from 46.3 per cent in 1957 to 48.3 per cent in 1963.[37]

On the third point,[38] the Canadian in-depth interview survey provides data on size of company and degree of patent utilization of a group of firms which Schmookler describes as large companies (see below). While the data do not contradict Schmookler's findings as between small and large companies, as he defines them, they do show that among large firms, size is related to ability and willingness to innovate.[39]

[33]United States industries have also advantages in other differentials in scale including size of plant and size of production runs.

[34]*Effective Protection in the Canadian Economy*, by James R. Melvin and Bruce W. Wilkinson, Special Study No. 9, Economic Council of Canada, Queen's Printer, Ottawa, 1968, p. iv.

[35]*Invention and Economic Growth, op. cit.*, p. 55.

[36]That is patents designed to keep other firms from utilizing an invention rather than the patentee doing so himself.

[37]Based on data excluding "not stated" as per Table 3, Appendix A, *Economic Implications of Patents, op. cit.*

[38]In support of Schmookler, the patent utilization rate in Canada of individual inventors (small businessmen), 20 per cent, is greater than that of corporate inventors (the bulk of patented inventions being made by large corporations), 15 per cent. (See Chapter 6, *Economic Implications of Patents, op. cit.*)

[39]In the sense of developing patentable inventions. (*Ibid.*, Chapter 7.)

Number of Companies	Average Sales per Company—$ Mill.	Patents Utilized as per cent of Total
4	85	10
4	324	14
7	436	28
15	313	17

On the fourth point, the Canadian in-depth interview survey supports the contention that business firms in North America rely in more recent times less on patent protection to innovate than in earlier periods. Of the 15 firms interviewed, those representing 65 per cent of gross sales indicated that patents had become a less important factor in their business generally during the last decade than previously. Large corporations suggested that in their industries more inventive activity was taking place in Canada without patent protection than with patent protection. Among the reasons given were that some inventions were not patentable while others could be utilized more profitably by not divulging the details required to be made public under the patent legislation so as to give the innovating firms a head start on their competitors and reduce the incidence of "patenting around" the original invention.

Abandonment of Inventions

The literature is replete with references to the contributions which innovations make to economic development. But not all innovations are commercially successful. Consumers may not take to new articles and their production may be abandoned. New machinery and equipment and improved processes may become quickly obsolete as new and more economic ways to produce are developed and utilized. Rapid change in computer technology is an example. Ventures to exploit new inventions may fail for a variety of reasons, from lack of financing to inexperienced management, from a dearth of production know-how to ineffective marketing methods.

The point was made previously that if an invention is patented in Canada, the likelihood of it being utilized in this country is one in six; if it is patented in the United States, it is likely to be one in two. The average useful life of inventions patented and worked in Canada averaged 7.7 years, while the same invention patented and worked abroad averaged 8.6 years.[40]

Once inventions are commercially utilized, the abandonment ratios in Canada and the United States appear to be quite similar, between one-quarter and one-third. In a way, these abandonment ratios are illustrative of the uncertainty and the risk factors involved as entrepreneurs struggle to keep abreast of technological progress. They can expect that between two-thirds and three-quarters of their innovational efforts may stand the test of the market and thus become commercially successful, with the remaining innovations representing part of the costs of the innovative process. This means that successful innovations

[40]Based on Tables 3 and 4 of Appendix A, *Economic Implications of Patents, op. cit.* The average useful life of inventions would be greater than the figures indicated above because some of the inventions were still being worked when the survey was undertaken.

not only have to produce sufficient returns to entrepreneurs to justify the risk entailed in introducing them, but also to pay for the costs of innovations which turned out not profitable.

The results of patent utilization studies in Canada and the United States are summarized below. There are differences in the timing of the surveys and classifications, limiting a direct comparison of the results. Still the data suggest broad similarities. The United States ratios vary between 24 per cent and 35 per cent.[41] But since patents assigned were more numerous than those unassigned, a weighted United States average would be a little higher than the Canadian proportion of 28 per cent. Interestingly enough, the abandonment ratio of inventions patented in Canada by United States firms, 22 per cent, is less than that of other non-Canadian firms, 34 per cent, and of Canadian firms, 35 per cent.

	Patents Abandoned as per cent of Total Used	
Canada (granted in 1957, 1960 and 1963 as of 1969)[42]		
Owned by Residents of Canada	35	
Owned by Residents of the United States	22	
Owned by Residents of Other Countries	34	
All Patents		28
United States (granted in 1938, 1948 and 1952 as of 1956)[43]		
Assigned to Large Companies[44]	38	
Assigned to Small Companies[45]	31	
Assigned to All Companies[46]		35
Not Assigned[46]		24

Innovations and Research and Development

To what extent does R & D contribute to innovational activity in Canada? The main impact of R & D expenditures results from the formulation of new ideas leading to inventions which, when put to practical use by entrepreneurs, become innovations with numerous consequences on economic development. There is a wide gulf between R & D and innovations. The former creates a potential of ideas. But it is only when businessmen decide to take the risk and marshal the necessary factors of production, including in particular management

[41]The abandonment ratios would be greater in the chemical and electrical industries because of a higher obsolescence rate in these sectors as compared with the rest of industry, as well as for other reasons. (See *Invention and Economic Growth, op. cit.*, p. 52.)

[42]Based on patents worked in Canada. (See Tables 4, 5, 28, and 29, Appendix A, *Economic Implications of patents, op. cit.*)

[43]Based on data developed by Barkev S. Sanders and summarized in *Invention and Economic Growth, op. cit.*, p. 49.

[44]Large companies are companies holding over 100 patents, or with some patents and over $100 million in assets.

[45]All companies except those classified large.

[46]At date of issue.

skills, to utilize these new ideas, that potential benefits to society are turned into actual benefits.[47]

In Canada, the gulf between R & D and innovations is greater than in many countries, quite apart from the fact that Canada devotes a smaller proportion of her total output to R & D than most industrialized nations.[48] Only a comparatively small portion of innovational activity can be traced to Canadian R & D efforts. There are several reasons for this:

1. The structure of R & D. Canada places greater emphasis on fundamental research and less on developmental work than most industrialized countries. The distribution of total R & D expenditures in Canada in 1967 was as follows: fundamental research, 23.1 per cent, applied research, 38.0 per cent, and development, 38.9 per cent. The corresponding figures for the United States were 14.1 per cent, 21.6 per cent and 64.3 per cent, and for the United Kingdom, 11.0 per cent, 24.4 per cent, and 64.6 per cent.[49]

2. In Canada, business is responsible for a much smaller proportion of financing R & D and government for a much greater proportion than is the case in most industrialized countries. The proportion of R & D expenditures financed by business and government in Canada in 1967 was 37.7 per cent and 35.6 per cent The corresponding figures for the United States were 69.8 per cent and 14.5 per cent, and for the United Kingdom, 64.9 per cent and 24.8 per cent respectively.[50]

3. Even where business carries out R & D in Canada, its ability to translate new ideas into innovations employed in the production of goods and services is somewhat less than that of entrepreneurs in other countries such as the United States, Germany and Japan. In the United States particularly, the quality of management, access to capital, merchandizing skills, strong motivational factors and a climate favourable to technological progress[51] have contributed largely to the superior performance of many business enterprises in utilizing inventions. Estimates based on the in-depth interview survey indicate that inventions resulting from R & D undertaken in Canada by foreign-owned corporations may be up to 50 per cent greater than the number obtained by Canadian owned firms, on a roughly comparable basis.[52]

4. The bulk of innovational know-how in Canada comes from abroad.[53] In the main, it is either acquired through licensing or through intercompany transfer of technology from foreign parent companies to Canadian subsidiaries, sometimes paid for in full, but more often made available without any or with

[47]This assumes that the direct beneficial effects exceed net negative externalities.

[48]R & D expenditures as a per cent of GNP in 1967: United States 2.9, United Kingdom 2.3, France 2.3, Netherlands 2.3, Switzerland 1.9, Japan 1.8, Germany 1.7, Canada 1.4. (See *A Science Policy for Canada*, Report of the Senate Special Committee on Science Policy, Chairman: The Hon. Maurice Lamontagne, Queen's Printer, Ottawa, 1970, p. 122.)

[49]*Ibid.*, p. 125.

[50]*Ibid.*, p. 128.

[51]See *Technological Innovation: Its Environment and Management*, U.S. Government Printing Office, Washington, D.C., 1967, pp. 8 and 14.

[52]*The Economic Implications of Patents, op. cit.*, Chapter 7.

[53]Canada is "importing *innovations* rather than inventions from the United States". This situation differs materially from the methods employed by Japanese industry which has developed great technical skills enabling it "to produce innovations quickly and successfully from *the inventions* of others". The Japanese experience, it is claimed, "has major implications for Canadian science policy". (*A Science Policy for Canada, op. cit.*, p. 120.)

only nominal charges (a bookkeeping entry if the subsidiary is fully owned and if there are not special tax advantages).

5. Foreign owned subsidiaries drawing on the technical and financial resources and managerial skills of their parent company are not only able to bridge more effectively the gap between R & D and innovations than do Canadian owned firms, they are also imbued by a greater spirit of adventure and willingness to take a similar long-term view to that of their parent companies when they devote a greater proportion of their resources to R & D.[54]

6. The structure of the Canadian economy differs from that of other industrialized countries, particularly the more mature economies like the United States. In Canada a substantial proportion of the goods-producing sector is devoted to primary activities where inventive activity plays a lesser role than in such highly sophisticated technologically oriented industries as electronics, aircraft, chemicals, military hardware, etc.[55]

Concluded the Senate Special Committee on Science Policy: "The available evidence on Canadian R & D output, although incomplete, is sufficient to justify the conclusion that Canada's innovative performance is low compared with that of most other industrially advanced countries. The Canadian inventive record may be better but statistics on patents issued in Canada, which constitute a reliable measure of the number of inventions, show that even here Canada has not been too successful, in spite of the relatively large number of qualified scientists and engineers engaged in R & D."[56]

Having set out some of the negative aspects of the relationship between R & D and inventive activity in Canada, [57] what are some of the positive features?

1. To the extent that the number of patents granted can be taken as an indicator, the four leading innovating sectors in Canada are the chemical products, electrical products, machinery and transportation equipment industries.[58] They are responsible for about 80 per cent of all patents granted and 58 per cent of R & D expenditures made by industry in Canada (see Table 1) and they provide employment for 11 per cent of the total number of persons working in

[54]"The R & D expenditure can be expressed in a series of ratios: in relation to turnover, to assets and profits. These three ratios agree. Firms under non-Canadian financial control quite definitely spend more on R & D than the Canadian firms. Secondly, there is hardly any difference between the behaviour of firms under United States control and those controlled by other non-residents. Both of these categories spend something like one-sixth of their profits on R & D as against only one-thirteenth in the case of Canadian firms." (*Reviews of National Science Policy, Canada*, OECD Publication No. 26233, Paris, 1969, p. 251.)

[55]There is the counter argument that the growth of the tertiary sector in Canada has been rapid in recent decades and that the Canadian economy more and more resembles the structural pattern of the United States. Hence, the primary industry argument may have been valid in an earlier period but it is less applicable to the 1970's, when Canada has reached a stage more "advanced" than the industrialized nations of Europe. (See *A Science Policy for Canada*, *op. cit.*, p. 150).

[56]*Ibid.*

[57]The effects of R & D activities on product development vary greatly. A special survey of 57 large firms indicated less than 5 per cent of sales consisting of "new" products arising out of intramural R & D. The electrical group was an exception with the proportion exceeding 50 per cent in several cases (*Business Abroad: The Canadian Case*, by D. F. McKinley, unpublished Ph.D. thesis, University of Ottawa, 1971).

[58]Excluding the residual group of "other" manufacturing.

industries which utilize patented inventions.[59] Most of the R & D expenditures are made by a comparatively small number of large firms in these four industries which have substantial advantages of scale as compared with other industries. The scale advantage works out on an *average* to about three-and-a-half times that available to all other manufacturing firms.[60] But in fact it is much larger at the upper end of the scale, e.g. comparing say the three largest motor car companies with the three largest textile firms.

2. Most of the inventive activity was concentrated around seven industrial products.[61] They made up about 40 per cent of all patents granted: agricultural machinery, motor cars and parts, electrical industrial apparatus, components and accessories, plastic and synthetic resins, industrial chemicals, and drugs and medicines.[62]

3. The in-depth interview survey indicated that the 15 large firms canvassed had increased their R & D expenditures between the 1963–1966 annual average to 1967 by 38 per cent, or better than 10 per cent per annum. The urge to innovate was a main factor.[63] Reasons given included: (1) essential to growth of company, (2) competition, (3) increased range of products, (4) keeping pace with technological progress, (5) increased sophistication on the part of management, (6) change in corporate philosophy, and (7) greater awareness of the benefits of the protection provided by patented inventions.[64]

4. The urge to innovate has become sufficiently strong so that firms interviewed, which representing 60 per cent of total R & D expenditures made, indicated that the Canadian patent system did not influence the size of their R & D programme. The impression gained was that most of the R & D efforts in Canada would continue if this country had no patent system or if the protection currently provided under the patent system would be considerably reduced.[65]

5. The major factor influencing the size of the R & D programme was competition,[66] so said 9 companies out of the 15 firms interviewed, representing

[59]In terms of employment in manufacturing the proportion of 24 per cent and in terms of total employment 6 per cent.

[60]In 1963, the year to which the data in Table 1 apply, the *average* firm in the 4 industries mentioned above had gross sales of $2.7 million as compared with $0.8 million for all other manufacturing firms. (Data from *Manufacturing Industries of Canada*, 1963, Dominion Bureau of Statistics, Ottawa, June, 1966.)

[61]The situation is similar to that in the United States where there is a heavy concentration of innovating activity in a few industries and in a few products, handled by a comparatively small number of large firms. (See *Technology, Economic Growth and Public Policy*, by Richard R. Nelson, Merton J. Peck, and Edward D. Kalachek, The Brookings Institution, Washington, D.C., 1969, p. 65.)

[62]See Table 20, Appendix A, *Economic Implications of Patents, op. cit.*

[63]Rising R & D costs were another factor.

[64]*Economic Implication of Patents, op. cit.*, Chapter 7.

[65]*Ibid.*

[66]This is similar to the position taken by large American firms: "No firm in competition with a few others can afford to let its rivals steal a march upon it as far as the technological base of its competitive position is concerned. The research and development work is essential for the maintenance of its position . . . It seems not very likely that the patent system makes much difference regarding the R & D expenditures of large firms." (See *The Production and Distribution of Knowledge in the United States*, by Fritz Machlup, Princeton University Press, Princeton, N.J., 1962, pp. 169 and 170.)

63 per cent of total R & D expenditures.[67] Government assistance was a minor or no factor, so said 11 companies respresenting 99 per cent of R & D expenditures made.[68] This situation is quite different from that in the United States where business relies heavily on government financial support and contracts in science-oriented industries.[69]

That there is *a* link between R & D and inventive activity that may lead to innovations can be reasoned on *a priori* grounds. But whether the link is as close as is claimed for the United States,[70] or ephemeral or loose, as appears to be the case in Canada, that is the question.

Mansfield produced a model separating returns from a firm's own R & D programme from those obtained through the utilization of technical know-how obtained elsewhere. This enabled him to estimate marginal returns from R & D expenditures. He found (1) that a firm's rate of technical progress was directly related to the rate of growth of R & D expenditures; and (2) that a firm's ratio of R & D expenditures to sales or its growth rate did not exert an important influence on its rate of technical change.[71]

Schmookler has presented estimates of R & D expenditures and the number of patents pending in 18 major industries in 1953. He worked out a coefficient of determination between the two variables of 0.848, "signifying that about 85 per cent of the inter-industry variation in patenting is explained by the variations in expenditures on research and development."[72] He further divided the industries into two groups of nine according to the amount of R & D expenditures and he ran separate regressions. "The two groups of industries did not exhibit statistically significant differences. The coefficient of correlation, *r*, was 0.84 for the nine industries with the highest volume of research and development expenditures, and 0.90 for the nine with the lowest volume; and the differences between the constant terms and the differences between the regression coefficients for the two groups were also not statistically significant."[73]

Schmookler concluded: "Since over 80 per cent of the inter-industry differences in patenting in 1953 are accounted for by the corresponding differences in research and development expenditures despite the existence of apparently significant impediments to a high correlation, reasonable grounds exist for using patent statistics as an index of inter-industry differences in invention during the year."[74]

[67]Though not quantified, the U.S. experience appears to be similar: "In the absence of reliable objective criteria, a considerable part of the R & D decision making process appears to involve reaction to, and imitation of, the policies of competitors." (See *Technology, Economic Growth and Public Policy*, *op. cit.*, p. 74.)

[68]*Economic Implications of Patents*, *op. cit.*, Chapter 7.

[69]"In the United States, industry is about 47 per cent self-sufficient in R & D as opposed to about 82 per cent in Canada." (See *A Science Policy for Canada*, *op. cit.*, p. 146.)

[70]There is some dispute about this claim. For example, in discussing Schmookler's paper on "Technological Change: Economic Theory", Zvi Griliches commented: "There is some evidence that the rate of investment affects the level of patenting or R & D effort, but very few links have been forged at the aggregate level between these and the rate of technical change as conventionally measured." (*American Economic Review*, May 1965, p. 344.)

[71]"Rates of Return from Industrial Research and Development", by Edwin Mansfield, *American Economic Review*, May 1965, pp. 320 and 321.

[72]*Invention and Economic Growth*, *op. cit.*, p. 44.

[73]*Ibid.*, p. 46.

[74]*Ibid.*, p. 47.

With respect to the more recent period, particularly the 1960's, Schmookler qualifies by saying that patents fail "to reflect the great upsurge of corporate invention."[75]

Calculations similar to those presented by Schmookler using 12 industry classifications covering data for 1963 (see Table 1) showed much greater tenuousness in the relationship between R & D expenditures and patents granted.

TABLE 1

PATENTS, SALES, RESEARCH AND DEVELOPMENT EXPENDITURES, AND NET PROFITS, TWELVE INDUSTRIES, CANADA, 1963

Industry	Number of Patents Granted	Sales $ million	R & D Expenditures[a] $ million	Net Profits as Percent of Equity[b]	Number of patents per $ million of Net Profits	Number of patents per $ million of Capital Invested[c]
Chemical Products	1,694 (1)	1,772 (9)	31.1 (4)	11.3 (4)	17.11 (2)	1.27 (3)
Other Manufacturing	1,250 (2)	9,756 (1)	38.5 (2)	8.1 (9)	2.49 (6)	0.18 (7)
Electrical Products	1,116 (3)	1,846 (8)	41.6 (1)	10.8 (5)	16.66 (1)	1.62 (2)
Machinery	577 (4)	1,377 (10)	7.6 (7)	9.4 (8)	9.78 (3)	2.79 (1)
Transportation Equipment	451 (5)	2,853 (5)	31.5 (3)	17.0 (1)	3.01 (5)	0.55 (4)
Pulp and Paper	169 (6)	4,288 (3)	13.6 (5)	10.4 (6)	0.60 (8)	0.07 (9)
Petroleum, Natural Gas, and Mining[d]	161 (7)	2,602 (6)	9.4 (6)	11.6 (3)	0.32 (10)	0.02 (10)
Textiles	136 (8)	2,383 (7)	2.1 (12)	13.1 (2)	1.35 (7)	0.19 (6)
Rubber	113 (9)	481 (11)	2.2 (11)	8.1 (10)	7.53 (4)	0.52 (5)
Food and Beverages	67 (10)	5,306 (2)	5.5 (8)	10.0 (7)	0.34 (9)	0.11 (8)
Other Non-Manufacturing[e]	49 (11)	—[f]	5.1 (9)	—[f]	—[f]	—[f]
Transportation and other Utilities	16 (12)	3,555 (4)	4.7 (10)	7.8 (11)	0.05 (11)	0.01 (11)
Total Manufacturing	5,573	30,062	173.7	9.9	3.79	0.41
Total Twelve Industries[g]	5,799	36,219[h]	192.9	9.8[h]	2.49[h]	0.14[h]

Source: Number of patents granted from *Economic Implications of Patents*, by O. J. Firestone, University of Ottawa Press, Ottawa, 1971; sales, net profits and equity from *Industrial Corporations, Quarterly Financial Statistics*, 1962–1969. Dominion Bureau of Statistics, Ottawa, 1970; R & D expenditures from *Industrial Research and Development Expenditures in Canada*, 1963, Dominion Bureau of Statistics, 1965. (Numbers in brackets reflect ranking.)

[a]Covers current and capital expenditures.

[b]Net profits are before income taxes; equity is that held by shareholders including paid-in capital and retained earnings at the end of 1963.

[c]Covers book value at the end of 1963.

[d]Covers primary operations only.

[e]Covers agriculture, fishing, primary forestry and construction.

[f]Not available.

[g]Total twelve industries employed 3,210,000 persons or about one-half of the total of 6,375,000 in 1963 (see *The Labour Force, Supplement to March 1965*, Report, Dominion Bureau of Statistics, Ottawa, 1965).

[h]Excluding Other Non-Manufacturing.

[75]*Ibid.*, p. 55.

The Canadian coefficient of determination for the 12 industries worked out to 0.694. Dividing the 12 industries into two groups, the six industries with the highest volume of R & D expenditures showed a coefficient of correlation of 0.752, and those with the lowest volume of 0.581. Not only were the Canadian correlations less close than those indicated for the United States, but also the difference between the coefficients of correlation for the two size groups was greater in Canada than in the United States. What are some possible explanations?

1. Some reasons are purely statistical. The industrial groupings differ, the year varies, the U.S. computations are based on patents pending and the Canadian computations on patents granted.

2. Other reasons are qualitative. Most of the R & D work done in Canadian industry takes place in the science-oriented sectors, largely by U.S. controlled firms. Some of the subsidiaries are given a good deal of freedom in selecting the area of specialization in which their R & D efforts take place. But a number of subsidiaries are assigned fields of enquiry by their parent companies which wish to take advantage of inter-country cost differentials, special access to government and academic research, availability of skilled professional personnel, etc. Most parent companies endeavour to avoid unnecessary duplication of R & D between their own laboratories and those of subsidiaries operating world-wide. The effect of this practice is that the area of R & D by Canadian subsidiaries is frequently decided on what fits best into the global pattern of multi-national corporations rather than on what might over the long term be in the best interest of the subsidiary operating in Canada. Thus, differences in the composition and orientation of R & D efforts may have a distinct bearing on the extent of inventive output that flows from making the expenditures in the first place.

3. Still other reasons are quantitative. They refer to the scale of the R & D efforts and their productivity in terms of inventive results[76] that flow from them and that are capable of practical utilization. In many instances the scale of R & D expenditures is much smaller on a per firm basis in Canada than in the United States. One of the consequences of the scale differential is a proportionally lower inventive output per $ million of R & D expenditures in Canada than in the United States. A number of studies undertaken in that country[77] indicate that up to a certain size of firm and scale of R & D spending, inventive efforts increase more than proportionally to size. But at a certain level "which varies from industry to industry, the fitted curve has an inflection point and among the largest few firms innovational effort generally does not increase and may decline with size."[78]

[76]This covers not just the number of inventions but also their quality, economic viability and value in the market place.

[77]"Size of Firm, Oligopoly, and Research: The Evidence", by D. Hamberg, *Canadian Journal of Economics and Political Science*, February 1964; "Size of Firm, Market Structure, and Innovation", by Edwin Mansfield, *Journal of Political Economy*, December 1963; "Bigness, Fewness, and Research", by Jacob Schmookler, *Journal of Political Economy*, December 1959; and "Industrial Research and the New Competition", by J. S. Worley, *Journal of Political Economy*, April 1961.

[78]"Market Structure, Business Conduct and Innovation", by Jesse W. Markham, *American Economic Review*, May 1965, p. 329.

Domestic and Foreign Innovations

Earlier, the point was made that as Canada's industrial expansion widened and deepened, her dependence on the inflow of technical know-how from abroad increased. In the previous section it was explained that Canada's R & D efforts are not bringing forth the quantity of inventive activity that could be expected if the resources in the science area were more effectively utilized. As a result, Canada continues to depend for some 90 per cent of her technology on other countries.[79] Estimates of the dependence of the United States on foreign technology affecting economic growth range between 10 per cent[80] and 50 per cent (the latter described as a "very generous estimate").[81]

The question arises: What are some of the economic consequences of Canada's great reliance on foreign innovational activity? The statistical sample survey shows:

1. Inventions are less likely to be utilized in Canada if they are foreign-owned than if they are domestically owned: U.S. owned 16 per cent, other foreign 6 per cent, and Canadian 51 per cent.[82]

2. Licensing agreements are more difficult to obtain from foreign than from Canadian patentees. Proportions of patents for which licence agreements were made: U.S. owned 13 per cent, other foreign 6 per cent, and Canadian 15 per cent.[83]

3. The main benefits of inventions are more likely to accrue to foreign than to Canadian patentees because the former prefer and are able to develop their inventions through wholly or largely owned subsidiaries or other affiliated companies while Canadian patentees are more likely to sell or licence their inventions to others. Proportion of inventions worked through affiliated companies:[84] U.S. owned 56 per cent, other foreign 75 per cent, and Canadian 4 per cent.[85]

4. To the extent that patents are indicative of innovational activity, foreign corporations rely to a much greater extent on patents in relation to capital investment than do Canadian firms. To illustrate in terms of numbers of patents granted per $10,000 of capital invested in industry in Canada in 1963, Canadian owned 1, United States 29, other countries 43, all countries 14.[86]

[79]Some 90 per cent of all inventions patented in Canada were also patented abroad (after adjusting for Canadian owned patents, see Table 26, Appendix A, *Economic Implications of Patents, op. cit.*).

[80]*Technology, Economic Growth and Public Policy, op. cit.*, p. 65.

[81]*The Sources of Economic Growth in the United States and the Alternatives Before Us*, Supplementary Paper No. 13, Committee for Economic Development, New York, 1962, p. 234.

[82]See Table 27 in Appendix A, *Economic Implications of Patents, op. cit.*

[83]See Table 35, *ibid.*

[84]Large foreign companies operating in Canada undertake more R & D in relation to their total resources than do Canadian companies of comparable size. A special survey of R & D activities of 57 firms (with positive results obtained from 48 firms) showed the following differentials in research intensity measured in terms of employment of scientists and engineers engaged in R & D. More than 1 per cent: Canadian-owned 7, foreign-owned 17; less than 1 per cent: Canadian-owned 14, foreign-owned 10; ratio: Canadian-owned 1 to 2; foreign-owned about 2 to 1. The survey also showed a fairly strong relationship between above average product diversification and high R & D intensity (*Business Abroad: The Canadian Case, op. cit.*)

[85]See Table 34 in Appendix A, *Economic Implications of Patents, op. cit.*

[86]Estimates based on data, the sources of which are given in Table 1.

5. Foreign innovators rely more on protection than do Canadians. In answer to the question whether the Canadian patent system was of fair or major significance in the decision to work their inventions, the replies were as follows: U.S. owned 60 per cent, other foreign 63 per cent, and Canadian 51 per cent.[87]

6. The greatest concentration of patenting activity is in the industrial sectors with the largest concentration of foreign control: transportation equipment (78–97 per cent), chemicals (78 per cent), electrical products (77 per cent), and petroleum and natural gas (74 per cent). These four industries obtained 61 per cent of all patents granted. Since about 94 per cent of all patents granted were held by non-Canadians, this means that this group of industries was responsible for two-thirds of all patenting activities in Canada. They outpaced not only Canadian innovational activity but also that of all other foreign controlled companies operating in Canada. The patent protection obtained reinforced the overwhelming dominance of these foreign firms in the key industrial sectors of the Canadian ecnonomy.[88]

The in-depth interview survey shows:[89]

1. Foreign innovators are more dynamic than Canadian innovators.[90] This can be illustrated in two ways: (a) foreign firms representing 60 per cent of gross sales were responsible for 93 per cent of patents obtained in 1967 while Candian firms with 40 per cent of gross sales obtained 7 per cent of all patents granted; (b) the ratio of patents pending to granted in 1967 was: foreign 3.3 and Canadian 2.6.

2. Foreign innovators are more likely to invent around the patented inventions of others than Canadian innovators. An example is the patented technology of Goodrich's synthetic vinylidene cyanide fiber known as Darlan. This product is similar chemically to vinyl cyanide otherwise called acrylonitrile. There are already three acrylonitrile fibers on the market—Orlon made by Du Pont, Acrilan made by Chemstrand and Dynel made by Carbide. Each of these three commercially available fibers is a copolymer based on acrylonitrile as the main component and differ one from the other by the second copolymerizable material. The existence of patents held by Du Pont on its fiber did not deter Chemstrand from developing Acrilan nor did the patents of Du Pont and Chemstrand deter Carbide from developing Dynel. Each apparently found a way around the prior patents just as Goodrich found a way around the prior basic research of the other companies.[91]

3. Many licences issued to firms operating in Canada by foreign patent owners contain restrictive clauses as to their utilization either in Canada or abroad, or both. These restrictive clauses are as a rule not subject to public scrutiny and they frequently limit Canadian firms and subsidiaries of foreign corporations in their ability to export to other countries even though the firms concerned may be competitive.

[87]See Table 42, *ibid.*

[88]See Chapter 5, *ibid.*,; comparable data are not available for the machinery industry.

[89]See Chapter 7, *ibid.*

[90]In some industries, it is claimed that Canadian technology is as advanced as in any other country, e.g. pulp and paper industry, STOL aircraft, farm machinery, ice breaker construction, cobalt treatment.

[91]*Chemical Week*, November 12, 1955, p. 81.

The data presented above appear to give the impression that the benefits accruing to non-resident innovators are notably greater than those flowing to Canadian innovators. But this is only part of the story. The Canadian economy as a whole has benefited greatly from the inflow of know-how from abroad for much of it has been accompanied by foreign capital, technical skills and managerial experience, which combined with abundant natural resources available in Canada and growing domestic and foreign markets have produced rates of economic growth and improvements in real incomes and living standards which otherwise would not have been attainable in the time it took to realize them.

There is the further point that drawing on technical knowledge developed abroad is frequently the most economical manner of introducing innovations into an economy like Canada's where the market is considerably smaller than that of the countries where most of the inventions originate. This, as a general argument, may be persuasive. But some case studies undertaken in the United States and the United Kingdom raise the question whether this generalization does necessarily apply. These case studies show that the costs of utilizing foreign technology may be quite high and in some instances it may be more economical to develop new technology at home.[92] As Arrow observed: "Considerable investment must be made to make use of knowledge",[93] and this appears to apply even more so if the knowledge is non-indigenous. This raises the question whether Canada should be looking more closely at some of those gifts of "free" or "near-free" foreign technology to ascertain whether they in fact serve the best national interests.

As the process of economic development proceeds and national consciousness becomes more keenly felt and vocal, two other questions are raised. One is: Can Canadians not become more effective innovators? The other is: Is the price Canadians are paying for continuing access to the world pool of technical knowledge and its use in Canada too high?[94]

Innovations and Profitability

Do cross-section data indicate a relationship between inventions and R & D expenditures on the one hand and profits on the other? Remembering the inadequacy of patent statistics as indicators of inventive and innovational activity, and the tenuousness of the link between R & D expenditures and innovations in Canada, one would expect little or no correlation between these variables.

[92]"The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations 1920 to 1950", by Willard F. Mueller, and "Inventions in the Postwar Aluminum Industry", by Myron J. Peck, both in *The Rate and Direction of Inventive Activity*, *op. cit.*, and "Research and Development in Electronic Capital Goods", by Christopher Freeman, *National Institute Economic Review*, November 1965.

[93]"Comments", by Kenneth J. Arrow, in *The Rate and Direction of Inventive Activity*, *op. cit.*

[94]The answers to these questions vary but shorn of qualifications the answers are generally, —yes. (See *A Science Policy for Canada*, *op. cit.*, *Report on Intellectual and Industrial Property*, *op. cit.*, and *Foreign Ownership and the Structure of Canadian Industry*, Report of the Task Force on the Structure of Canadian Industry, Privy Council Office, January 1968, Queen's Printer, Ottawa, 1968.)

In part this is due to the inadequacy of the Canadian data. The problems faced are twofold.

First, the data cover main industrial groupings which permit broad generalization but fail to provide sufficient detail of disaggregation to enable the investigator to trace the effects of certain variables, e.g., R & D expenditures, through a sequence of events which ultimately tests their raison d'être—the contribution they make to business profits. For the latter is the reward the entrepreneur expects when he makes the R & D expenditures in the first place and then takes the risk of seeing through some of the new ideas from their stage of emanation to the creation of the final product and its marketing.

Some case studies have demonstrated that there exists indeed a causal relationship between R & D expenditures, increase in productivity and profitability.[95] But the trouble is that the evidence gathered appears to be applicable to the industries examined, with investigators warning that "it would be reckless to generalize these results to cover the entire economy."[96]

Second, there are many variables which affect the level of profits and the profitability of investment, but few of them can be effectively isolated to permit adequate measurement. Some of these variables would have positive and some negative effects on earnings so that the analyst who looks at net earnings examines in effect the result of two sets of influences working in opposite directions.

Presumably, R & D expenditures and inventive activity contribute to increases in net earnings, if not over the short term, then over the longer term, for otherwise the entrepreneur may sooner or later examine this type of activity with a cost-cutting gleam in his eye. But there may be numerous unrelated factors affecting an industry's profits that makes one wonder how effective cost benefit analysis really is when it comes to attributing the contribution that R & D expenditures and inventive activity make to the overall earnings of a company. Even if it is assumed that every firm makes rational decisions, there will be different time lags between the making of R & D expenditures and inventions, the introduction of innovations, and the earning of profits. The latter in turn will be affected by market, organizational and institutional forces.[97] Other factors include random occurrences and differences in the quality of management, the manner of financing, the type of organization, the scale of operations, the share and penetration of the market, the degree of competition, etc. Thus industry totals of net profits become largely a hodgepodge of conflicting and

[95]Based on examining 18 firms in the chemical and allied products industries and 5 firms in the drug and pharmaceutical industries. (See "The Economics of Research and Development", by Jora R. Minasian, *The Rate and Direction of Inventive Activity, Economic and Social Factors*, Proceedings of Conference of the Universities—National Bureau Committee for Economic Research, and the Committee on Economic Growth of the Social Sciences Research Council, Princeton University Press, Princeton, N.J., 1962, pp. 93–141).

[96]*Ibid.*, p. 141.

[97]The implication is that Schumpeter's sequence, invention, innovation and imitation, inspiring as it was when first put forward, does not fully meet the requirements of analysis. (See *The Theory of Economic Development*, by Joseph Schumpeter, Harvard University Press, Cambridge, Mass., 1934.) The modern investigator is concerned with the broader context and a wider spectrum of sequences encompassing cause and effect as advances in knowledge find their way into the working of the economic system. (See for example, "Scientific Discovery and the Rate of Invention", by Irving H. Siegel, in *The Rate and Direction of Inventive Activity*, *op. cit.* p. 445.)

diverse forces at work resisting attempts to isolate and weigh the various factors that in combination produce the end results.[98]

If available data are so inadequate, why look at them at all? The answer is: They are indicative of a certain order of magnitudes as between industries suggesting that most business firms know what they are doing when they undertake R & D activity and innovate, even though a *direct* link between technological progress and profitability cannot be adequately demonstrated. The data in Table 1 show:

1. Of the four leading industries in terms of numbers of patents granted,[99] three were also leading in terms of R & D expenditures (chemical products, electrical products and transportation equipment), with only the machinery industry ranking outside the top four grouping.

2. Of the four leading industries in terms of numbers of patents granted, three were also leading in terms of net profits as per cent of equity, and one was outside the grouping, covering the same industries as under (1).

In terms of relative profitability,[100] three of the leading industries were either considerably or to a fair degree ahead of average earnings of all industries obtaining patents, while the fourth leading industry was only slightly below the average: transportation equipment 73 per cent, chemical products 15 per cent, electrical products 10 per cent, and machinery industry −4 per cent.

3. All four leading industries in terms of numbers of patents granted were also leading in terms of number of patents per $1 million of net profits. The development of inventions and their utilization was essential to these industries if they wanted to stay ahead in the technological race and remain leading income earners. The percentage difference between the number of patents per $1 million of net profits of the lead industries as compared with the average of all industries was as follows: chemical products 586 per cent, electrical products 567 per cent, machinery industry 292 per cent, and transportation equipment 21 per cent.

4. All four leading industries in terms of numbers of patents granted were also leading in terms of number of patents granted per $1 million capital invested. The lead of the lead industries is indicated when comparing their performance with that of other sectors. The number of patents per $1 million of capital invested for the lead industries varied between 0.55 for the transportation equipment industry to 2.79 for the machinery industry, as compared with 0.41 for all manufacturing and 0.14 for all industries covered.

5. The coefficient of correlation for the twelve industries covering patents granted and R & D expenditures was 0.885 and the coefficient of correlation for eleven industries[101] covering net profits as percent of capital invested (book values of capital stock) and R & D expenditures as a per cent of capital invested

[98]For an attempt to assess the various factors contributing to cost differentials of a number of articles manufactured in Canada and the United States, see *Scale and Specialization in Canadian Manufacturing*, by D. J. Daly, B. A. Keys, and E. J. Spence, Staff Study No. 21, Economic Council of Canada, Queen's Printer, Ottawa, 1968.

[99]Excluding other manufacturing.

[100]That is in terms of percentage difference between the ratio of net profits to equity for leading industries and the average for *all* industries covered.

[101]Data on capital invested were not available for the twelfth industrial grouping, other non-manufacturing.

was 0.521. The lower correlation indicated for the last two mentioned variables as compared with the first two mentioned variables reflects the influence of the many diverse factors affecting net profits, referred to earlier, and the difficulties faced in attempting to isolate one particular influence on a residual, called net profits.

Admittedly, available data are quite inadequate. Still there are sufficient indications that the science-oriented sectors of the economy are among the most innovation-minded, and that investment in R & D and inventive activity may bring substantial returns. It is mainly the large corporations that can take advantage of such opportunities. In fact they have to do so if they want to continue to remain leaders in their industries and they are able to do so because they run profitable operations. Thus the gulf between big business and smallfry is widening, and so are the growth opportunities as between industries and regions, the latter affected by their ability, or lack of it, to attract the science-oriented industries.