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innovations techniques
Rapport de recherche**

THE INTERNATIONAL TRANSFER AND LICENSING
OF TECHNOLOGY IN CANADA

Russel M. Wills

February 1982

#83



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of the authors and are not necessarily endorsed by the
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* D.P. Demelto, K. McMullin, and R. Wills, "Innovation and Technological Change in Five Canadian Industries," The Economic Council of Canada, Ottawa, 1980.

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EXECUTIVE SUMMARY

This report is based on interview and survey data of 167 firms in five Canadian industries concerning 283 of the most profitable products and manufacturing processes introduced by the firms between 1960 and 1980. Ninety-six (34 %) of the products and processes were based on external technology and 187 (66 %) based on in-house R&D.

Sources of Technology

If we examine the specific sources of external technology for products, we find that Canadian-controlled firms relied on equipment suppliers in over 40 per cent of the respective cases. Suppliers were not used at all as technology sources for products by foreign-controlled firms, which relied on their parent firms in 83 per cent of the respective cases.

With respect to sources of process technology, Canadian-controlled firms used consultants and foreign-controlled firms used parents both in over 50 per cent of the respective cases.

But aggregating only in terms of comparative percentages of products and processes, we are giving the same weight to a product or process costing \$ ten thousand as one

costing \$ hundred million. Another indicator of their contribution to the Canadian economy is the total expenditures the firms made on the products and processes.

Collectively these 283 products and manufacturing processes cost the firms more than \$1.3 billion. Although foreign-controlled subsidiaries constituted a little over half of the responding firms, subsidiaries were responsible for 87 per cent and 75 per cent of all expenditures on manufacturing processes and on products respectively.

If we look at products and processes based on in-house R&D, subsidiaries were responsible for 75 per cent of the expenditures on products based on R&D and 84 per cent of the expenditures on manufacturing processes based on R&D.

When we examine products and manufacturing processes based on external technology adopted from outside the firm, subsidiaries are responsible for 97 per cent of expenditures on such products and 93 per cent of expenditures on such manufacturing processes. Thus although the R&D to sales ratio is higher for Canadian-controlled firms in our sample than for subsidiaries, the main source of technology for these profitable innovations has been the foreign multinationals, both as R&D performers and as importers of technology.

Rapidity of Transfer

The lag rate is the number of years between first world commercialization or use of a product or process and first Canadian use. It is a measure of how rapidly Canadian firms are incorporating new technology into products and processes.

Although there is no significant difference in lag rate for products between foreign and Canadian controlled firms, -- averaging about 6.5 to 7.5 years -- the lag for processes was almost a decade shorter for subsidiaries and amounted on average to 5.9 years. The average lag rate for processes of Canadian-controlled firms was 15.3 years.

Sources of Technical Information

Government institutes for scientific and technical information, written sources, independent inventors and universities were not significantly used as sources of awareness knowledge for new product or process technology or as an aid in subsequent problem solving during development.

Customers were most often used as idea sources for new product technology by both foreign and Canadian-controlled firms, and suppliers of equipment were comparatively used as an idea source by small and medium-sized Canadian-controlled firms more than twice as extensively as by foreign-controlled subsidiaries of the equivalent sizes.

Forms and Mechanisms of Transfer

When firms obtain external technology, what precisely is being transferred -- blue prints, prototypes, patent rights, designs or engineering specifications? What mechanisms are firms using to obtain the technology -- parent-subsidiary transfers, imitation by adoptive R&D, one-time purchases of know-how, joint ventures or licenses?

Although technology transfers of turnkey projects certainly involve the transfer of equipment, (and many of our transfers involved the purchase of components), most transfers were effected in the form of blueprints, designs, software tapes and specifications, plus personnel exchange, continuous phone interaction and even computer messaging. Even in heavy processing industries transfers seldom involved equipment and prototypes. Such was characteristic both of arms-length and parent-subsidiary transfers.

The benefits are portability of designs and instructions -- international transfer of equipment may involve significant moving costs -- and the necessity of having human carriers to apply the technology in a new context.

The main mechanism was the parent-subsidiary transfer. Joint ventures with unaffiliated firms were prevalent only in crude petroleum.

Licensing to Canada

Licensing was not found to be a significant means of obtaining technology in our sample of 283 profitable products and manufacturing processes. Licensing technology occurred in only 29 cases (10 per cent) of our sample, and these accounted for less than 12 per cent of the total expenditures.

Over half of the licensed processes were licensed to large firms, while small and medium-sized firms were the main licensees for product technology.

Foreign-controlled firms comprised 89 per cent of all licensees for manufacturing processes, and only one Canadian-controlled firm licensed a manufacturing process.

Restrictions on Licenses and Transfer Agreements

Most of the transfers between parent and subsidiary were not covered by specific licenses but often by unwritten transfer agreements -- wherein, for example, the subsidiary gains access to the results of the parent's R&D for a yearly flat fee.

Products

About half of the license and transfer agreements to Canadian-controlled firms for products provide for a continuous flow of technology, but 85 per cent of product agreements by subsidiaries are continuous, including access to future technology developed by the source firms.

About half of the license and transfer agreements for product technology with foreign-controlled firms were written, but almost all such agreements with Canadian-controlled firms were in written form.

With respect to rights such as the right to manufacture or sell the product, and exclusive rights for manufacturing and sales, there is little difference between foreign and Canadian-controlled firms. But only 26 per cent of the agreements with Canadian-controlled firms for products restrict manufacturing to Canada, while 40 per cent of the product agreements with subsidiaries thus restrict manufacturing.

Twenty per cent of the product agreements with Canadian-controlled firms limit sales to Canada, while 36 per cent of such agreements with subsidiaries limit product sales to Canada.

Processes

Agreements and licenses by Canadian-controlled firms for processes were mainly one-time, while agreements of subsidiaries were continuous in 71 per cent of the respective cases. There were only 10 cases of process technology transferred to Canadian-controlled firms.

The territory of manufacture under a process was restricted to Canada in over a third of the agreements with subsidiaries and in no agreements with Canadian-controlled firms.

The territory of sales using a process was restricted exclusively to Canada in only 15 per cent of the process agreements with subsidiaries and in no process agreements with Canadian-controlled firms.

The requiring of specific input sources and the reservation of rights to improvements made in the technology were not present in any agreements for process technology by foreign-controlled subsidiaries; finally no significant differences were found in restrictions and conditions between written and unwritten agreements.

Licensing and Sales of Technology from Canada

Forty-one (15 %) of our 283 products and manufacturing processes had associated technology licensed or sold from Canada to other countries and firms.

A little over a third of these 41 were for processes and slightly under two-thirds for products.

Over half of the licensing in the other direction was done by foreign-controlled subsidiaries, which were responsible for 73 per cent of all cases of licensing or sales of process technology from Canada. Licensing was used often to gain access to foreign markets to which national governments had otherwise forbidden entry, rather than to make a direct profit from the sale of a specific technology.

Most of the licensing from Canada involved products and processes based on original R&D performed in Canada.

INTRODUCTION

For the past decade attention has been focused on developing policies to promote the indigenous high technology development of new products and manufacturing processes. Existing studies have often indicated that Canada is an importer of technology and that commercial development of manufacturing technology has been somewhat limited.

Two repeatedly cited factors felt to be responsible for the "innovation gap" between the United States and Canada are the shorter production runs of Canadian as compared to U.S. firms, and the consistently high level of foreign ownership in Canadian industry. It is felt that shorter production runs make the creation of new production technology less profitable in Canada, since development costs are spread out over comparatively limited customers; foreign ownership, it is thought, restricts the domestic creation of new technology, since it is often quicker and cheaper for foreign subsidiaries to import technology from their parents.

As a complement to the promotion of indigenous production technology, some policies have focused -- also for more than a decade -- on the more rapid adoption of existing foreign technology; it is believed that "adaptive and imitative" excellence is a more realistic strategy for many Canadian industries and firms.

In fact, a concern on the part of the Canadian government with technology transfer goes back more than a hundred years. Tom Naylor* writes that in

"1853, the government of Canada itself got into the act of trying to facilitate the influx of US techniques in the agriculture implements industry. William McDougall was sent to the US to examine patented machinery and report on the possibility of its introduction into Canada. The Department of Agriculture published his report along with detailed descriptions of certain coveted machines. In 1857, the matter of technological transfers was again in the fore with the reorganisation of the administration of the Patent Law. The fact that the Department of Agriculture was empowered to administer patent matters demonstrated clearly the type of American technology that was most desired by the overwhelmingly agrarian province. That year, two boards of Arts and Manufactures were established in both parts of the United Provinces on which academics, agricultural experts and representatives of the boards of trade and of the Mechanics Institutes of the two regions would sit and promote the diffusion of technical

*Tom Naylor, The History of Canadian Business 1867-1914, Vol. One the Banks and Financial Capital, (Toronto, James Lorimer and Co., Publisher, 1975, pp. 42-43).

knowledge in general, and the establishment of exhibitions of models of foreign agricultural implements in particular.

"It was largely through Canadian interest in promoting the influx of American technology in the agricultural implements industry that the pattern of Canadian patent legislation took shape. In 1849, the first general Patent Act of the Province extended the validity of Upper Canada or Lower Canada patents to both parts of the United Province of Canada. And it stipulated that the machinery from the U.S. and other parts of British North America could continue to be imported freely. Thus no Canadian patent could interfere with the influx of U.S. technology. In 1857, the Act was extended further. Any Canadian was free to pirate technology from abroad and patent it, except from the U.S. and the Empire. Canadian patents could not be issued that would interfere with the free diffusion of American technique. American patents could be freely copied, but the pirating could not become the legal prerogative of any one person. It was generally felt that by leaving the whole field of U.S. manufacturing open to Canadian mechanics and manufacturers, they would quickly appropriate everything valuable for reproduction at home, especially for agricultural implements. In fact this

failed to occur on the desired scale. Canadian capitalists often could not shoulder the heavy fixed costs necessary to produce under American patents..."

Given the possible productivity gains of microprocessors in manufacturing processes and given the massive possible spin-off effects and potential R&D exports of technology involved in large capital projects, such as the oil sands, this old issue of producing or rapidly adopting and adapting technology will become increasingly important.

One problem in doing industrial research in this area in Canada is that data upon which to base policy decisions is often lacking. Thus during 1979-1980, the author, Dennis Demelto and Kathryn McMullin designed and conducted a full sectoral survey of "innovation" in five Canadian manufacturing industries for the Economic Council of Canada and the Department of Industry, Trade and Commerce. These industries were crude petroleum production and exploration, telecommunications equipment and components, non-ferrous smelting and refining, plastics and synthetic resins, and electrical industrial equipment.

Respondents were asked to identify and describe three "innovations" -- either created by their firm through R&D, or adopted from outside the firm -- which had most contributed to the firm's profitability. The time period involved was from 1960 to 1980.

For purposes of the survey an "innovation" was defined as a major new/improved product or production process, and it was left to the firms to decide what constituted "major, new" products and processes, subject to the profitability constraint. Thus new meant new to the adopting unit, even if it had been previously used or commercialized elsewhere. Information was sought on the nature of the innovations reported -- whether they were new or improved, original or initiative, whether they were patented in Canada, information about the pay-back period for the firm's R&D expenditures on the innovation to pay off, and the number of competitor firms.

Information was also sought on the year of the firm's commercial launch or use of the innovation, the commercialization period (the number of months elapsed between the firm's first significant employment of resources on the innovation to its first commercial launch or use), and the lag rate, that is, how rapidly Canadian-based firms were incorporating new technology into their products and production processes.

Questions were also asked about the sources and costs of technology for the innovations, about characterizations of (and restrictions on) licensing agreements for such technology, and about sources of ideas for the innovation.

Questions were asked about the labour effects of the innovation on production and non-production workers, about effects of the innovation's introduction on the structure of the firm, and about the nature of spin-off products resulting from initial R&D.

In addition, economic information was collected on the size of the firm and country of control, total annual sales, annual sales of the products, the amount spent on R&D, the number of employees in the firm, etc.

The questionnaires were first sent to all firms in the five industries on November 13, 1979, and a follow-up mailing to non-respondents was completed on January 4, 1980. Firms which had still not responded a month or so after the second mailing were then telephoned and urged to complete the questionnaires. Of the 410 firms in the five industries, 170 returned one or more questionnaires, for an overall response rate of 41 per cent.

A preliminary analysis of the survey is contained in an Economic Council Discussion Paper.* This is a report to responding firms on the survey results and does not contain analysis of reporting biases or of the statistical significance of the data.

*D.P. De Melto, K. McMullen, and R. Wills, "Innovation and Technological Change in Five Canadian Industries," Economic Council of Canada, 1980.

It does however, provide original information of direct relevance to current Canadian industrial policy discussions. This report will concentrate on two issues in the survey, namely, the transfer and licensing of technology for these profitable products and manufacturing processes.

Also of particular importance is the foreign ownership issue. Given the generally small size and lack of corporate ties of Canadian firms and the generally enormous costs of process innovations, foreign firms, we shall see, are the main vehicles of new technology for Canada.

Having first described the innovations and commented on effects of microprocessors in the five industries, we shall examine the source of the innovations' underlying technology.

With respect to actual sources, what factors influence firms to choose a specific external technology source -- suppliers, customers, consultants, parent firms, etc.? Furthermore, what are the mechanisms and forms of specific transfers -- what are firms getting and how are they getting it -- and what is involved on a sectoral basis with respect to transfers? In what forms is technology imported? Do Canadian firms get manufacturing technology significantly later than firms in other industrialized nations, and how do they search for technical information?

Much attention needs to be given to the meaning of licensing and transfer restrictions in Canada. In previous studies of licensing agreements for international transfer of technology, it has been found that technology obtained via license is usually quite old and may prove to be quite expensive in the long run. Two studies of the transfer of American microprocessor technology by license also found that firms do not often license out technology which is incorporated into products whose life cycle has not peaked. Thus we will examine the extent of licensing and license restrictions. To the extent the data allows, we have also examined reverse flows of technology -- from Canada to the world.

In obtaining this data over seventy interviews were held with representatives of Canadian and US firms in the five industries. Interview and survey information was supplemented by firm level financial reports, the Form 10 K Report which is annually filed with the U.S. Securities and Exchange Commission.

For convenience of reference, footnotes have been placed at the bottom of each page.

DESCRIPTION OF THE INNOVATIONS - TELECOMMUNICATIONS EQUIPMENT

The telecommunications equipment industry forms a subset of the larger communications equipment (SIC 335) group, and also includes portions of the electronics, wire and cable and office equipment (computers) groups of the SIC code. Traditionally, the main products included in this industry have been exchange, transmission, and subscriber equipment. But with increased chip complexity and a massively increased content of silicon in telecommunications products during the 1960s and 1970s, traditional product boundaries in this industry are blurring.

Exchange Equipment

In exchange equipment one of the main technological innovations reported was the digital multiplex system (DMS). Employing digital techniques for carrying the information they are switching, DMS's have call-handling capabilities which are many times greater than the old cross-bar and step-by-step switching equipment.

Other exchange equipment reported in the survey included chip-based systems for connecting a large number of computer terminals to computer services, systems for identifying

the calling number in long-distance calls, systems which allow subscribers to use standard phone lines for voice or data transmission, systems for long-distance direct dialing, components which eliminate large electro-magnetic crosspoint devices in phone-switching networks, trunk selectors, and systems for placing telephone calls from mobile vehicles automatically.

Transmission Equipment

One of the main technological changes in the past decade in transmission equipment involves digital transmission such as the millimetre wave-guide and fibre optics cable, both achieving call-handling capabilities much greater than existing coaxial cables or micro-wave relays.

In the millimetre wave-guide, signal-carrying radio waves are transmitted through an underground tube. (The wave-guide was developed in connection with the video telephone, which necessitated a higher capacity than normal voice communication for video signals). Such wave-guides are of real use only on high-density communication networks such as between major urban areas.

Fibre optics systems utilize a light-emitting diode which is modulated by either a voice or a digital signal, and tiny glass cables in place of copper wires. Although

apparently little is known about how long fibre optics cables themselves will last, such optical transmission systems, in contrast to existing paired-wire systems, have higher capability, smaller size, and a high degree of compatibility with existing data transmission systems. It is believed by industry experts that by the time really high capacity is needed on the existing long-distance networks, fibre optics systems will have proved reliable and cost-competitive in long-distance, high-density areas of transmission.

It is thought that during the transition period to the fibre optics transmission systems, another type of radio transmission, called single-side band radio will be used. With minor equipment modifications, single-side band radio can more than triple the capacity of existing microwave networks.

Transmission equipment reported in the research included multi-core fibre optics cable, optical fibre directional couplers, coaxial cables with lower attenuation, ultra light field telephone wire, and packet-routing systems for facsimile data.

Satellites

With satellites, costs are independent of transmission distance, and it is expected that one-way transmissions such as

cable satellite networks and data traffic will be the most important uses. Satellite innovations reported in the survey included transportable satellite earth stations, automatic satellite data-collection systems such as for the collection and transmission of meteorological data, and components such as cross-wave filters for use in satellite communications, amplifiers which receive microwave signals and amplify them for transmission to orbiting satellites, and so forth.

Silicon and Telecommunications R&D

Microprocessor technology has widely invaded all aspects of the Canadian telecommunications industry, from computer-based switchingsystems to systems for automatically answering calls to disconnected numbers, to computerized quality control systems for the automatic analysis of signal loss and noise and the automatic testing of (older) cross-bar equipment. Other innovations involved the computer generation of wiring information and the computer testing of connections, the use of extensive plug-in printed wiring cards in the manufacture of switching systems, and chip-based digital data test-sets for modems and data terminals.

Chip-based telecommunications technology also has facilitated cheap, reliable supervisory and control devices. Amongst the innovations reported were many supervisory and

control systems to report alarms, systems for telemetry metre-reading, to monitor unattended microwave repeater sites and pipeline pumping stations.

As the telecommunications technology has migrated from an analogue, electro-mechanical base to a digital, silicon chip-base, experts* have noted major developments in telecommunications R&D: first there has been an increase in the number and types of participants -- involving the software industry, business equipment manufacturers, cable equipment manufacturers, aerospace industries, computer industries, and the whole complex of micro-electronics industries. Secondly, telecommunications equipment research has been "internationalized", with multinationals doing research in the areas of solid state devices, switching and transmission equipment, and terminals.

With this massive increase in chip complexity and micro-miniaturization, there is a real blurring in telecommunications equipment of product boundaries. Separate products now no longer incorporate distinct capabilities as they previously did, as for example with PABXs, computers, copiers

*Manley R. Irwin, Telecommunications and Public Policy: Exploratory Options Amidst Technological Change, preliminary draft, undated.

and facsimile machines. Now a single product can incorporate many functions of such technologies. Many PBXs, for example, include accounting capability in addition to switching and can also route electronic messages, as can word-processing machines hooked together. As the differences between telecommunications, data processing, office equipment, and mail, blur and blend, the regulatory imperative may become not merely difficult, but impossible.

CRUDE PETROLEUM INNOVATIONS

The main technological changes reported in crude petroleum extraction and exploration in Canada involved the development of the oil sands, enhanced recovery techniques for conventional oil and the oil sands, the development of oil production off-shore, and advances in seismic interpretation technology. Other advances involve new drilling and fracturing techniques, new drilling mud additives which improve the stability of water-sensitive shale during drilling, and new electronic well log techniques. Some of the innovations were made by field operating personnel in the 1960's and 1970's and, for the most part, are unique operating procedures.

Off Shore Exploration and Development

In Canada there have been major improvements in the technology of off-shore exploration and development, involving more stable production from drilling platforms, increased depth capabilities in drilling, and new computer-based equipment for the remote monitoring and controlling of sub-sea operations. Innovations in this area included ice drilling platforms (which involve modifications of the conventional land drilling rigs), ice platforms supported on artificially thickened ice, new techniques of off-shore well completion beneath the arctic ice, equipment such as ice cutting semi-submersible drilling vessels capable of maintaining their positions under heavy moving ice conditions, air cushioned transport vehicles, and new metallurgical techniques required for sub-sea well and well-head equipment. In arctic areas, exploration innovations included techniques to package drilling and transportation equipment and other equipment for air transportation, and the use of helicopters and specially equipped launches for seismic monitoring purposes.

Exploration Innovations

Exploration innovations involved major advances in seismic interpretation techniques based on computer methods of processing and interpreting seismic data. Seismic exploration

and data interpretation innovations varied from simple digital recording of seismic data, (a comparatively recent development), to the use of interactive computer graphics in interpreting geophysical data, techniques for suppressing multiple reflections before data recording in seismic exploration, to the recognition of subsurface astroblemes from seismic shotline patterns.

Incremental Innovations

Many of the innovations in crude petroleum at least partially resulted from field operating personnel in incremental day-to-day procedures, for example, the blending of condensate with crude to allow more economic pipeline transportation, the development of desanding systems and treating vessels, new inflatable packers for drill-stem testing, and systems for pumping and treating highly viscous crude oil containing almost a third by volume of sand.

Development of the Oil Sands

The Athabasca oil sands is the largest of Alberta's several heavy oil deposits. It comprises more than a hundred billion cubic meters of bitumen (heavy oil) in place. Other deposits are at Cold Lake (25.2 billion cubic meters of bitumen), Wabasca (6.1 billion cubic meters) and Peace River (10.3 billion cubic meters). These latter contain deposits too deep to

recover by surface mining methods, and ultimately some "in situ" techniques must be utilized. It is often estimated that the four deposits will ultimately produce approximately forty billion cubic meters of synthetic crude oil.

The earliest advocate of a hot water flotation method of separating bitumen from sands was Sydney Ells, an engineer working with the federal Department of Mines, who began this work with the oil sands in 1913. One of the Alberta Research Council's scientists, Dr. Carl Clarke, had initiated experiments since the early 1920's with the hot water flotation process in which oil, sand, and hot water were mixed and the resulting slurry was aeriated, separating into a froth of bitumen and a clear layer of sand which would settle to the bottom of the tank.

The first significant producer of oil from the sands, Great Canadian Oil Sands Ltd., began construction of their plant in the early 1960's and started producing oil in 1967. The Syncrude Canada Ltd. operations came on stream in 1964, but due to the discovery of oil reserves in Prudhoe Bay, it was then thought by the federal government that there was a surplus of conventional oil, no potential for the oil sands projects, and several applications of Syncrude to increase production were rejected. In September of 1973, the Alberta government and the members of the Syncrude consortium reached royalty agreements.

Over the past two decades, a lack of stability in pricing and royalty rules and continuous squabbling between the province of Alberta and the federal government have seriously delayed the development of the oil sands. Although Alberta and Ottawa finally concluded an oil pricing agreement in 1981, some oil sands operations have remained shut down, because running them is still uneconomical.

Enhanced Recovery Techniques

To understand the importance of the enhanced recovery innovations for Canadian energy self-sufficiency, one must understand something about the nature of oil reservoirs and current "primary" recovery techniques.

Oil reservoirs consist of porous rock which contain water, oil, and gas under pressure. The primary production of the oil is accomplished by displacing it toward the producing wells. As this displacement occurs, unless the reservoir is naturally pressure maintained, the pressure the oil is under declines, reducing the oil flow, and some artificial secondary means must be created to prevent the decline, usually involving the injection of gas or water into the reservoir. When this injection procedure is exhausted, there is still approximately two-thirds of the original oil left in the reservoir. This oil is the goal of the enhanced recovery techniques.

It has been estimated* that of the approximately 36.1 billion barrels of conventional oil in Alberta, only 32 per cent or 11.4 billion barrels will be recovered by such primary and secondary techniques. This will leave 24.7 billion barrels in the ground. Of this oil remaining in the ground, 68 per cent or 16.7 billion barrels exists in reservoirs which share some affinity for enhanced recovery techniques.

It is further estimated that for Canada as a whole, about 61 per cent of the potential enhanced recovery will derive from miscible and immiscible gas processes, 36 per cent will come from thermal processes, and 3 per cent will come from chemical processes. For Alberta alone, where most of Canada's oil reserves lie, about 78 per cent will come from thermal processes and 5 per cent from chemical processes**.

Although much is understood about how the injection of water and various chemicals affect the characteristics of both the oil to be recovered and the porous rock formation itself, these techniques remain basically a black art. Though many of the enhanced recovery techniques are variants of old procedures, in a sense they are innovative each time they are applied to a

*J. Phillip Prince, Enhanced Oil Recovery in Canada, Canadian Energy Research Institute, Study No. 9, March 1980, ISBN-0920522/09/2, p. 25.

**Ibid., p. 27.

different reservoir because the results can never be predicted without prior field experimentation. An enhanced recovery technique that works perfectly in one reservoir might not work a half mile away.

Thermal Advanced Recovery Techniques

The main objective of all enhanced recovery techniques involving the introduction of heat to the reservoir -- such as fire-flooding, cyclical and continuous steam injection, wet combustion, and reverse combustion -- is simply to reduce the oil's viscosity or thickness and allow it to flow more easily. The heat can be injected into the reservoir externally via hot water or steam, or may be produced "in situ" by literally cooking a portion of the reservoir's crude.

Chemical Enhanced Recovery Techniques

Chemical enhanced recovery techniques -- such as polymer, surfactant and alkaline flooding -- simply involve the introduction of chemicals into the water flood, and in hydrocarbon or carbon dioxide miscible flooding, the injected solution mixes with the oil, resulting in a solution that flows more easily toward the well-head. (Miscibility is merely a property of liquids which allow them to dissolve other liquids or gases.)

In addition, enhanced recovery techniques may involve combinations of the various techniques described above, such as steam simulation and production cycles followed by wet underground combustion.

Oil and Computers

One major advantage of computer analysis in exploratory and drilling operations is that it enables one to measure and correlate a large number of variables with high accuracy. Such monitoring systems have achieved major cost cuts in the United States by reducing chemicals used in drilling, increasing drill penetration rates, and reducing testing activities. However, the computerization of supervisory and control functions in crude petroleum extraction is just beginning in Canada, with several west coast electronic firms making initial overtures to the oil companies. (Several past attempts have failed. One firm, for example, tried to computerize an exploration technique involving an automated optical scanning system for digitizing log files. But since microprocessors are rapidly destroyed by hydrogen sulphide environments, there were massive mechanical breakdowns.)

In some cases, however, personal computers are being used to collate data from field pilot projects, including data on production rates and production pressures at short intervals from wells. Also in some of the oil sands operations, microprocessors

are being used. The composition of the sands in terms of the proportional content of oil, sand, water, and mineral rich clays, varies extremely from minute to minute in extraction plants as it passes along conveyers belts. Continuous adjustment of the extraction processes to the changing grades is required, and in some of the oil sands operations, there are electronic scanners to identify sand grades before the sand enters holding tanks.

The analytic technology currently in place is often "operator sensitive", and this sensitivity can cause problems if sands grades are nonlinear. Manufacturers are not developing on-line sensors since the uses are so specialized and the market is not large enough. But in several firms, microprocessor based systems for process control purposes are currently at laboratory scale and may be in production by 1984-85, depending on when the oil-sands plants are begun again.

Many data bases have, of course, been computerized, including production, core, seismic, reservoir modelling, and logging data. In some firms, senior management has given considerable thought to problems of introducing microprocessor related technology to crude petroleum production. It was felt however that the massive lack of qualified manpower -- encompassing virtually every job type -- would be even more pronounced if a constraining factor of operations were made more sophisticated.

The main future uses of microprocessor technology will be in the areas of monitoring and process control and in the entire area of connecting sensors and detectors to computer-guided machinery; however, present critical manpower shortages in this area prevent development. There simply do not exist trained people who have a good background in the sensor/detector field who are also knowledgeable in software.

INNOVATIONS IN NON-FERROUS SMELTING AND REFINING

With few exceptions, the innovations reported in this industry were process innovations.

The processing of mined and beneficiated ores involves the separation of a metal from its sulphide or other ore compounds. This process is called extractive metallurgy and may be divided into three groups: pyrometallurgy, in which heat is used to facilitate the extractive reactions; hydrometallurgy, in which the metal is leached from its ore via a solvent; and electrometallurgy, in which electricity is used to facilitate the removal of the metal. Some metals are extracted entirely by one or two of these methods, while others may involve combinations. Most of the rarer metals are produced as by-products of the processing of common metals.

Pyrometallurgical Innovations

Pyrometallurgical process innovations reported in the survey involved rotary furnaces, oxygen-softening for lead (a process involving the use of an oxygen air mixture bubbling through molten lead, which removes the antimony, arsenic and tin as oxides), blast furnace oxygen enrichment processes for lead blast furnaces, and process equipment such as wheel-breakers used to crack the crust of electrolytes in the reduction cells for the production of aluminum, and equipment for punching the tuyeres of converters (used in copper smelting operations whereby undesirable slag accumulated in the tuyeres is removed by forced air).

Electrometallurgical Innovations

Electrometallurgical innovations included the electric furnace smelting of ilmenite and electric furnace smelting to make matte anodes for electro-refining, the production of nickel crowns by electro-deposition (in which high-purity electro-nickel is produced as discrete entities as opposed to cathodes requiring shearing to size), and energy-saving bath additives which lower the melting point of electrolytes.

Hydrometallurgical Innovations

Hydrometallurgical innovations included the production of uranium hexafluoride and of ceramic uranium dioxide for CANDU reactors, pressure-leaching processes for zinc concentrates (in which high zinc extraction is attained without an additional residue retreatment step which is required with a conventional roast-leaching process), extraction processes of silver from complex arsenical concentrates without discharging pollutants into the atmosphere, the zinc hydrometallurgical process (in which a zinc plant purification residue is treated to recover a salable copper residue), processes for the recovery of zinc arsenate and its utilization in purification of zinc plant electrolytes, the controlling of pressure hydrogen reduction steps for recovering refined nickel powder from solution, pressure-leaching processes for treating mixed nickel/cobalt sulphide precipitate (recovered as a by-product from nickel concentrate treatment), the fluid-bed chlorination of granulated nickel oxide, and the production of high-purity granule or nickel from copper/nickel matte.

In addition there were, of course, production processes involving combinations of the above three, such as slurry feed-roast of copper/nickel concentrates for sulphuric acid recovery followed by electric smelting of calcine.

Chip Applications

Although there is extensive use of process computers in this industry, to date there have not been significant microprocessor impacts in smelting and refining. Even in some Canadian nickel refineries, the most modern in the world, there are not yet on-line computers for process purposes. Although this industry is a large user of computers for all types of off-line operations such as finance, design functions, and simulations, the reliability of sensor devices for monitoring and controlling processes are the largest bottlenecks to the evolution of chip applications. Robotics will have applications in the future in mining, although several past attempts have failed. Due to rising energy costs and pollution control problems, most North American smelters of certain metals have purchased or are anticipating the purchase of entire CAD/CAM-Emission Control Systems from the Japanese who have studied this technology for several years and now have perfected it.

INNOVATIONS IN PLASTIC COMPOUNDS AND SYNTHETIC RESINS

Innovations reported in the survey by this industry were mainly processes for the production and improvement of plastics and resins such as polyvinyl chloride and polyethylene.

The process innovations included the continuous (rather than batch) production of polystyrene, grinding processes for thermo-resins, faster, lower energy polymerization processes, new processes for cross-linkable polyethylene products, the mass resin process for the production of polyvinyl chloride resin, processes for the environmental containment of vinyl chloride during production to reduce employee exposure, new processing techniques for vinyl acrylic emulsion products, processes for the continuous production of thermo-setting phenolic powder adhesive, the dry blending of polyethylene mixtures, and the gas phase process for polyethylene. Again as in smelting and refining, although there is use of process computers in this industry, to date the impact of microprocessors is negligible.

ELECTRICAL INDUSTRIAL EQUIPMENT INNOVATIONS

Electrical industrial equipment (SIC 336) is comprised of products and processes for the generation, transmission, distribution, and conversion of electricity -- for applications with electrical utilities, resources and transportation industries, and primary and secondary manufacturing.

About half of the sector's output is comprised of heavy electrical industrial equipment such as power generators and drive systems for the petrochemical, mining, and steel industries. The other half is directed towards the electrical

power utilities companies, and includes such items as custom-built power generators and transformers.

The industry may be thought of as divided into firms which produce a large volume of high technology-based customized equipment, and firms producing high volumes of standard products. The first group of firms has a significant export business, with exports remaining at just under 10 per cent of domestic output over the past few years. The second group, those firms producing mass-produced items, is oriented mainly to the domestic market. The products emerging from this sector are diversified and ranged from custom-built turbines, generators, and transformers, to mass-produced components for electrical industrial users, to motor control and drive systems for petrochemical, steel, paper, and marine transportation systems.

Canadian technological expertise is concentrated in customized engineering products, while much of the technology in this industry (for standard products) is imported from parent corporations. With many of the multinational parents, the intention is to concentrate on advanced development work, mainly the incorporation of microprocessors into existing lines of products. Also several parent firms are becoming increasingly involved in robotics.

Process Innovations

Production processes reported in the survey included the use of programmable logic controllers to control indexing, positioning, and welding functions of automatic welding machines (thus permitting rapid change of control functions to adapt to tooling changes); on-line infrared-based sensors and analysers to optimize the manufacture of fine papers and coatings of papers; numerical controls for engine lathes (which enable the user to switch back and forth between an ordinary engine lathe and a highly sophisticated mass production machine without large capital expenditures), and robotic spot-welding and numerical control machines attached to minicomputers in the tooling area for automated cutting. In some instances, numerically controlled machines are being used to produce power transformers. Production processes also included various concepts of "containerizing" and delivering electrical industrial machinery-helicopter transportation providing transportable turnkey packages capable of being installed in populated areas or at completely isolated sites where construction materials are nonexistent.

Utilities Innovations

Innovations for the electrical power utilities companies ranged from power circuit air-breakers of improved performance and reduced costs to magnetic circuit breakers, high-voltage transformers, and shunt reactors.

Heavy Industrial Equipment Innovations

Industrial equipment innovations reported ranged from high-efficiency, heavy-duty industrial gas turbines for pipeline and marine-type drive applications, smaller steam and hydraulic turbines, specialty transformers for railroad traction services, hydro generators and stepping motors.

Control and Instrumentation Innovations

Control and instrumentation innovations often involved the basic conversion of conventional electro-mechanical control systems to solid state, resulting in reduced size, reduced cost, and increased reliability. Technology varied from solid state automatic transfer switches and controls to supervisory systems for use in pulp and paper, steel, utilities, refineries and other process industries; solid state time-delay relays; solid state programmable control systems which eliminate hard wiring of control logic circuits for use by process industries and machinery builders; measuring and control equipment using ultra-sonics air ranging (for noncontacting use with liquids and dry bulk material in the food, mining, cement and chemical industries) and vibration analysers for power, pulp and paper, petrochemical, pipeline, steel and machinery industries.

With this description of the technology involved in the study, we now turn to an examination of the sources of the technology.

SOURCES OF TECHNOLOGY

Canadian statistics on technology transfer do not represent the value or cost of technology transferred to Canada. The yearly several billion dollars that Canadian firms pay for the use of technology of foreign firms are contained in the "Business and Other Service Transactions" in Canada's Balance of Payments Statistics, and statistics periodically collected by the Corporation Labour Unions Returns Act (CALURA) indicate the breakdown of such payments. These are classified as royalties for the use of patents, copyrights, industrial designs, trademarks, fees for professional or engineering services, management fees, and R&D "rent" costs. Stead has pointed out* that "Many of these payments have nothing to do with technology" and that most of the classifications are ambiguous. For example much of the rent payments are for rental of machinery, and in some cases an alternative might be to include the machinery rental under a licensing agreement - similarly for management fees charged by some parent companies over items such as technical advice and documentation.

It's thus almost impossible to get valid data on financial transfers between affiliated firms, because parent firms use transfer pricing to maximize benefit to the multinational globally.

*Humphrey Stead, "Statistics on Technology Transfer between Canadian and Foreign Firms," Part I, December 1978, MOSST, p. 2.

Even so, Stead has produced some statistics which may give "extreme lower limits" for international technology transfer to Canada and which can delineate trends in transfer. The first, which is derived from MOSST'S annual survey of industrial R&D, measures payments in support of R&D as carried out in Canada.

Table 1

International Financial Transactions for Industrial R&D

Year	Payments by Canadian firms for foreign R&D		Receipts from non-residents for Canadian industrial R&D	
	\$000,000	Index - (1)	\$000,000	Index - (1)
1963	28.7		7.4	
1965	27.7	100	25.9	100
1967	34.8	121	16.9	62
1969	37.8	125	18.6	66
1971	51.6	163	23.5	80
1973	64.0	182	32.9	96
1975	78.3	161	41.1	84
1976	81.0	164	46.0	90

Source: Stead, op. cit., p. 4.

A second series of data, derived from the same source, deals with transfer costs for patents, licenses and technological know-how. (Both series of data deal only with firms performing industrial R&D, and the statistics don't pertain to firms which carry out such transfers but don't themselves perform R&D.)

Table 2

International Financial Transactions for Industrial Technology

Year	Payments by Canadian firms for foreign technology		Receipts from non-residents for Canadian industrial technology	
	\$000,000	Index - (1)	\$000,000	Index - (1)
1963	21.1	100	2.3	100
1965	27.6	128	3.0	126
1967	42.6	191	3.3	130
1969	62.3	265	2.1	82
1971	57.6	234	5.5	204
1973	77.8	285	5.0	159
1975	108.6	285	9.2	204
1976	127.8	333	7.7	163

(1) In Tables 1 and 2, payments and receipts are deflated by the GNE implicit price indexes for exports and for imports, then indexed to 1963=100.

Source Ibid., p. 5.

However, in both series, payments are increasing much faster than receipts.

Since the US is Canada's major technology trading partner, it is instructive to look also at US data.

Vernon and Davidson* looked at foreign subsidiaries of 180 US-based multinationals and the diffusion of 406 innovations and 548 imitations introduced by the multinationals. They found

*Raymond Vernon, W. H. Davidson, "Foreign Production of Technology Intensive Products by U.S.-Based Multinationals Enterprises," Boston, Mass., 1979.

that "firms are tending to set up overseas production sites for new product lines more speedily and more extensively in their subsidiaries abroad, trends that continue to accelerate into the 1970's" and that for innovations, the time lag between the U.S. introduction and first overseas production has been rapidly shrinking in the 70's (Table 3). In the first half of the 70's, there also has been an acceleration in the rate of which U.S. multinationals have been "building up their networks of subsidiaries and licensees for the production of technology intensive lines of new products in foreign countries. But familiar areas such as Latin American and Canada are losing their importance in the network of the multinationals in favour of Asia, Europe and Africa, with sales and liquidations of subsidiaries being highest in Canada and Latin America.

Stead's lower limits for the trends in the balance of technology payments hold, then, even though the comparative percentage of subsidiaries in Canada is decreasing over time.

Although in the present case, we are examining total costs (by source) of high technology products and manufacturing processes rather than the technology balance of payments, we find a similar dependence on foreign subsidiaries. Thus when we

Table 3*

Transfers of 406 Innovations by 57 U.S.-Based
Multinational Enterprises to their Foreign
Manufacturing Subsidiaries, Classified by
Period of U.S. Introduction

Innovations classified by period of U.S. introduction	Number of innovations	Percentage transferred abroad, by number of years between U.S. introduction and initial transfer						Average annual transfer rate from year of first foreign introduction to: ^{1/}	
		Same year or 1 year after	2 or 3 years after	4 or 5 years after	6 to 9 years after	10 or more years after	Total	3rd year there- after	1977 year end
1945	34	8.8%	14.7%	2.9%	11.1%	45.3%	82.8%	.926	.187
1946-1950	79	11.4	15.2	10.1	14.1	39.3	90.1	.947	.244
1951-1955	57	7.0	5.3	15.8	25.4	32.5	86.0	1.126	.265
1956-1960	75	16.0	21.3	16.0	20.0	18.7	92.0	.997	.269
1961-1965	63	26.9	17.5	14.3	7.9	8.1	74.7	1.160	.314
1966-1970	64	28.2	17.2	12.5	6.2	(a)	64.1	1.233	.453
1971-1975	34	38.2	26.2	(a)	(a)	(a)	64.4	(a)	.878
Total	406	18.7%	16.3%	11.6%	14.3%	20.2%	81.1%	1.017	.326

(a) not applicable

^{1/} Average annual transfer rates are compiled for individual innovations by dividing the number of foreign subsidiaries of the innovating firm in which production existed in 1978 by the number of years between the first foreign production of the innovation and 1978. These individual rates are then averaged to yield annual rates for any subject in the data base. In compiling this rate, innovations which have not been produced abroad are excluded.

*Source Vernon, op. cit., p. 38.

examine sources of external technology for products and processes separately across control (Tables 4-6), we find that for products, Canadian-controlled firms utilized equipment suppliers as sources of external product technology in over 40 per cent of their respective cases, while foreign-controlled firms did not use any suppliers for external product technology, relying on their parent or affiliate for product technology in 83 per cent of respective cases. (The reliance upon suppliers for process technology was, however, about 19 per cent for both Canadian and foreign-controlled firms.)

Table 4

Sources of External Technology
(N=96)

	Parent or affiliate	License or purchase from customer	License or purchase from supplier	Joint venture	Other licenses	Consul- tants	Total
Process	18 (42%)	3 (7%)	8 (19%)	3 (7%)	0 (0%)	11 (25%)	43 (100%)
Product	35 (66%)	2 (4%)	5 (9%)	6 (11%)	5 (9%)	0 (0%)	53 (100%)

Table 5
Sources of External Product Technology
(N=53)

Sources	Canadian	Foreign
Parent or affiliate	1 (8%)	34 (83%)
Customer (sales or license)	0 (0%)	2 (5%)
Supplier (sales or license)	5 (42%)	0 (0%)
Joint Venture	3 (25%)	3 (7%)
Other licenses	3 (25%)	2 (5%)
Total	12 (100%)	41 (100%)

Table 6
Sources of External Process Technology
(N=43)

Sources	Canadian	Foreign
Parent or affiliate	0 (0%)	18 (55%)
Customer (sales or license)	1 (10%)	2 (6%)
Supplier (sales or license)	2 (20%)	6 (18%)
Joint Venture	2 (20%)	1 (3%)
Consultants	5 (50%)	6 (18%)
Total	10 (100%)	33 (100%)

Foreign-controlled firms obtained process technology from their parents in over half (55%) of the respective cases, and consultants, (which were not utilized for product technology by either foreign or Canadian-controlled firms), were used by Canadian-controlled firms for process technology in 50 % of the respective cases.

However, if we aggregate merely in terms of numbers of innovations, it is rather like comparing apples and oranges. A product or process costing ten thousand dollars is given the same weight as one costing ten million. A more accurate reflection of their contributions to the Canadian economy is the innovations' total deflated costs - encompassing costs of basic and applied research, developments costs (such as engineering, design, prototype construction, and pilot plant construction), manufacturing and marketing costs. In Table 7 we have aggregated in terms of total deflated costs by firm control and source of technology. We were able to determine this total cost for 266 innovations.

These innovations collectively cost the firms more than 1.3 billion dollars. Innovations based on external technology comprised only 26 per cent of total costs while those based on R&D comprised 73 per cent of the innovations' total costs.

Although foreign-controlled firms comprise slightly more than half (52%) of the 167 responding firms, manufacturing processes developed by foreign-controlled firms accounted for 87 per cent of all expenditures on processes, and foreign-controlled products accounted for 75 per cent of the expenditures on products.

Innovations developed by foreign-controlled firms comprised 81 per cent of total expenditures on innovations based on in-house R&D and 91 per cent of the expenditures on innovations based on external technology.

As we examine products and processes separately, these differences across control become more pronounced. Foreign-controlled firms were responsible for 75 per cent and 84 per cent respective total expenditures on products and processes developed through in-house R&D, and for 97 per cent and 93 per cent of the respective total expenditures on products and processes based on adopted technology. Total expenditures on the innovations by industry are given in Tables 8-12. Clearly the foreign subsidiaries are a major source of technology for Canada.

Table 7*

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
(N=266)

	N	Mean	Median	Total
<u>Processes</u>				
Canadian, technology outside	9	2,416,564	267,380	21,749,080
Canadian, R&D	14	7,640,023	111,367	106,960,325
Foreign, technology outside	28	10,250,255	1 466,507	287,007,140
Foreign, R&D	23	24,994,348	1 075,107	574,870,003
<u>Products</u>				
Canadian, technology outside	11	759,184	227,407	8,351,021
Canadian, R&D	84	1 020,018	112,559	85,681,507
Foreign, technology outside	33	1 029,870	80,806	33,985,703
Foreign, R&D	64	3 915,488	316,249	250,591,235

*Tables 7-12 are in real 1971 dollars.

Table 8

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
Telecommunications Equipment
(N=106)

	N	Mean	Median
<u>Processes</u>			
Canadian, technology outside	3	218,917	267,380
Canadian, R&D	1	63,316	63,316
Foreign, technology outside	3	2,755,809	2,820,005
Foreign, R&D	2	211,834	211,834
<u>Products</u>			
Canadian, technology outside	7	1,061,830	293,664
Canadian, R&D	48	1,253,619	162,165
Foreign, technology outside	12	382,593	73,415
Foreign, R&D	30	751,465	274,167

Table 9

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
Crude Petroleum
(N=23)

	N	Mean	Median
<u>Processes</u>			
Canadian, technology outside	1	2,401,353	2,401,353
Canadian, R&D	3	13,227	12,484
Foreign, technology outside	11	13,560,920	1,261,705
Foreign, R&D	7	70,185,093	1,745,200
<u>Products</u>			
Canadian, technology outside	0	0	0
Canadian, R&D	0	0	0
Foreign, technology outside	0	0	0
Foreign, R&D	1	2,800,000	2,800,000

Table 10

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
Plastics and Resins
(N=38)

	N	Mean	Median
<u>Processes</u>			
Canadian, technology outside	1	3,928,815	3,928,815
Canadian, R&D	2	2,751,965	2,751,965
Foreign, technology outside	5	16,195,619	5,265,771
Foreign, R&D	4	1,785,459	1,587,097
<u>Products</u>			
Canadian, technology outside	0	0	0
Canadian, R&D	12	248,072	45,114
Foreign, technology outside	7	1,122,102	59,231
Foreign, R&D	7	672,147	366,017

Table 11

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
Smelting and Refining
(N=31)

	N	Mean	Median
<u>Processes</u>			
Canadian, technology outside	3	4,914,558	245,422
Canadian, R&D	5	20,258,284	875,146
Foreign, technology outside	8	6,068,603	660,356
Foreign, R&D	8	9,439,319	1,524,944
<u>Products</u>			
Canadian, technology outside	0	0	0
Canadian, R&D	1	11,239,047	11,239,047
Foreign, technology outside	2	8,398,516	8,398,516
Foreign, R&D	4	50,548,089	1,037,991

Table 12

Total Deflated Dollar Expenditures on Innovations
(by control and source of technology)
Electrical Industrial Equipment
(N=64)

	N	Mean	Median
<u>Processes</u>			
Canadian, technology outside	1	18,488	18,488
Canadian, R&D	3	20,659	7,399
Foreign, technology outside	1	42,672	42,672
Foreign, R&D	2	247,148	247,148
<u>Products</u>			
Canadian, technology outside	4	227,803	128,624
Canadian, R&D	20	151,365	24,800
Foreign, technology outside	11	176,622	80,806
Foreign, R&D	22	958,869	291,769

RAPIDITY OF TRANSFER (DIFFUSION AND LAG RATES)

The diffusion rate of an innovation pertains to the rapidity with which a population of potential adopters use it. Normally one thinks of the diffusion period as beginning when, say, a process has had at least one commercialization, (that is, has been demonstrated to be technologically and economically feasible to potential adopters), and as ending when some stable adoption level has been achieved. Some researchers, however, date the commencement of the adoption period as, for example, where 10 per cent of an industry's output is manufactured via the new process.

In spite of different dating procedures utilized in different studies, some consistent empirical results on industrial diffusion have emerged. For many different measures of adoption "intensity", such as the percentage of firms adopting a process innovation at time t , the diffusion pattern across time follows an S-shaped curve*. Thus the growth of the number of adopters is proportional to the product of the number who have

*Zvi Griliches, "Hybrid Corn and the Economics of Innovation," in The Economics of Technological Change, Penguin Books, Ltd., Middlesex, 1971; Edwin Mansfield, "Technological Change and the Rate of Imitation," in Industrial Research and Technical Innovation, W.W. Norton and Company, New York, 1968, Chapter 7; Rakha Agarwala, Everett M. Rogers, and Russel M. Wills, Diffusion of the Impact Innovations, Applied Communication Research, Palo Alto, California, 1975.

already adopted the innovation and the number of remaining potential adopters.

It is then assumed that industrial diffusion patterns can be "explained" by a wide diversity of economic/communicational variables -- such as the profitability of the production process as perceived by the potential adopter, the "perceived" technological compatibility of the process with the potential adopter's existing production techniques, resources available for financing, firm size, managerial factors such as age, previous job mobility and educational levels, of the firm's executives, the shortage of substitutable factor inputs such as labour, the rates of flow of information about the innovation, industrial concentration, and so forth.

Factors, however, found significant for both the time and extent of adoption in one study have been found insignificant in others.

An excellent discussion of existing Canadian empirical studies and the instability of their research results in both manufacturing and service industries is contained in works by Globerman.*

*Steven Globerman, "The Adoption of Computer Technology in Selected Canadian Service Industries," The Economic Council of Canada, 1981, and "Technological Diffusion in Canadian Manufacturing Industries, Department of Industry, Trade and Commerce, 1974.

In the following discussion we will examine a measure related to diffusion, the lag rate of an innovation, defined as the elapsed time between the first world commercial launch (for products), or first world use (for processes), and the responding Canadian firms' first commercial launch or use. Lag rate, as defined above, is a measure of how quickly responding firms in the industries are incorporating new technology into their products and production processes after that technology's first commercial world use.

Actual studies on the lag rates and the diffusion of new technology in the Canadian private sector is scant. Often it is thought that the close ties of Canada with the United States guarantee that state-of-the-art production technology in Canada does not significantly lag behind other countries. However, existing empirical studies yield contradictory evidence. One study of the diffusion of synthetic materials found that the production of a new synthetic first took place in Canada 14 years, on average, after it had been first produced in the originating country*. However, diffusion studies of innovations in the Canadian iron and steel industry found that, on average, Canadian firms adopted new production technology faster than U.S. firms**.

* G.C. Hufbauer, Synthetic Materials and the Theory of International Trade, Harvard University Press, Cambridge, Mass., 1966.

**David Ault, "The Continued Deterioration of the Competitive Ability of the U.S. Steel Industry: The Development of Continuous Casting", Western Economic Journal, August 1973, and H.G. Baumann, The Diffusion of the Basic Oxygen Process in the U.S. and Canadian Steel Industries, 1955-69, Research Report 7303, Dept. of Economics, University of Western Ontario, January 1973.

Globerman has conducted three such studies* -- examining the diffusion of numerical control machine tools, new processes to eliminate water in papermaking, and of tufting equipment in the manufacture of carpets -- duplicating diffusion studies of E. Mansfield in the United States. In all cases, the rate of diffusion by firms was significantly slower in Canada than in the United States, and slower than in Europe for the water press. Globerman also found significant lag rates between the date of initial use of the innovations in Canada and the initial use date in the originating country.

Vernon has been examining the interval between the first introduction of a new product in the United States and the first foreign production of that product by a subsidiary of the introducing firm. He finds that "The period between the US introduction and the initial transfer seems shrinking rapidly over the years from 1945 to 1975. For example, for the 79 innovations (in his sample) introduced in the United States between 1946 and 1950, only 26.6 per cent were being produced abroad by the third year following their US introduction.

*"New Technological Adoption in the Canadian Paper Industry", Industrial Organization Review, Vol. 4, 1976; "Technological Diffusion in the Canadian Tool and Dye Industry", The Review of Economics and Statistics, Vol. LVII, No. 4, November 1975; and "Technological Diffusion in the Canadian Carpet Industry", Research Policy 4, 1975.

That proportion, however, increases substantially with succeeding units of innovation, so that for the group introduced from 1971 to 1975, the proportion produced abroad by the third year following US introduction reaches 64.4 per cent."*

In the following, we will examine statistical variations in average lag rates, first by sources of technology -- whether the innovation's source of technology was research and development within the firm or was a transfer from outside. We will then examine variations in lag rates by type of transfer; that is, if the primary source of the innovation's technology was a transfer from outside, what is the variation in average lag rate between inter corporate transfers and arm's-length transfers? Finally we will examine variations in lag rate according to control (Canadian-controlled firms vs. foreign-controlled firms), and total cost.

Lag Rate by Source of Technology

Although any technological innovation really has a multiplicity of sources for its underlying technology, survey respondents were asked whether the primary source of technology for the innovation was research and development within the firm or was a transfer from outside their firm.

*Vernon and Davidson, op. cit., p. 39.

Average lag rates, by source of technology and by type of transfer, for all innovations together and by industry, are presented in Figures 1 to 6.

The average lag rate for all innovations was 7.8 years, and ranged from a minimum of 5.5 years for telecommunications innovations to a maximum of 11.5 years for innovations in smelting and refining. Production processes, on the average, took 1.3 years longer than products, although this difference is not statistically significant.

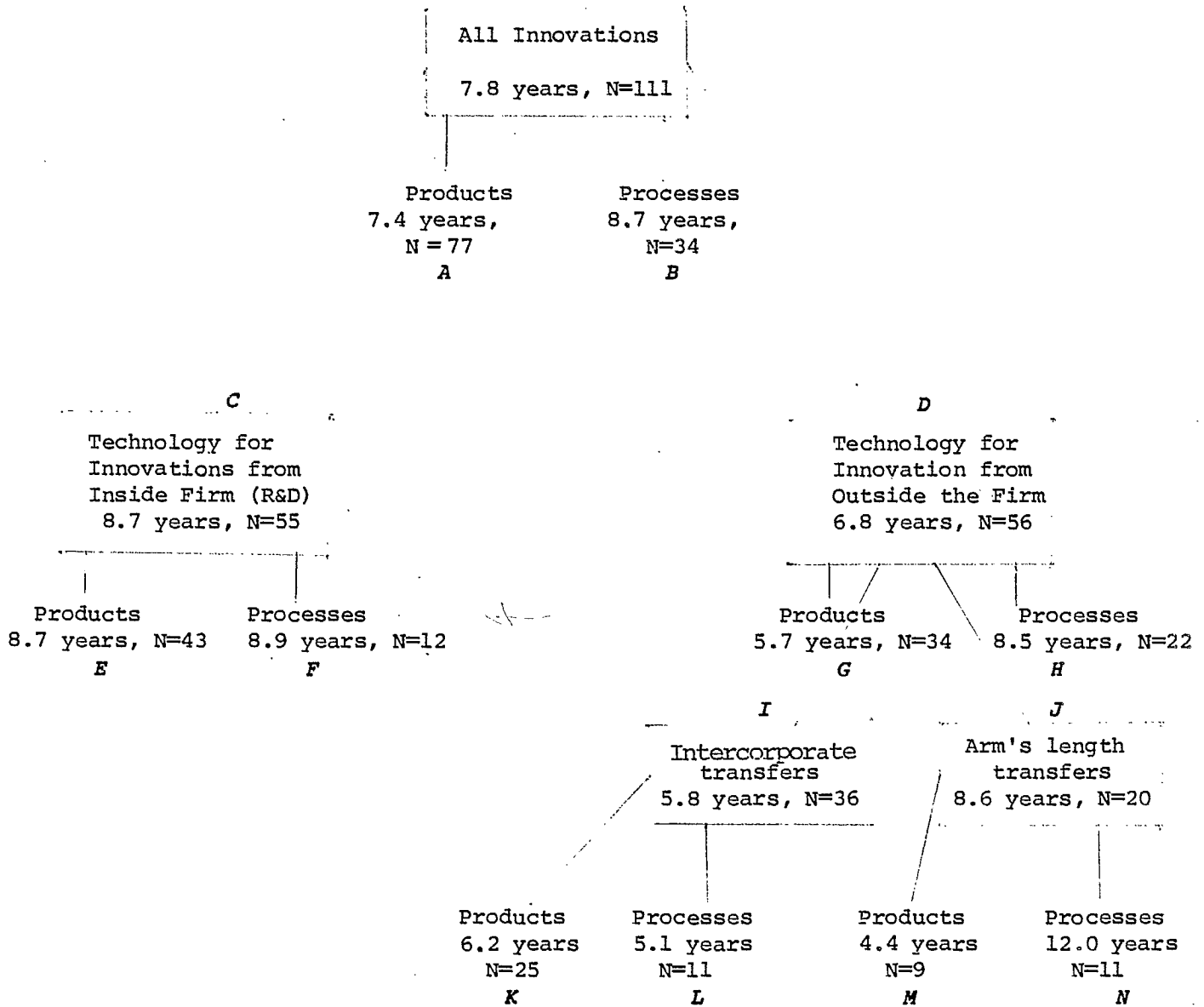
For innovations done by research and development, the lag rate was, on average, 1.9 years longer than for innovations in which the technology was obtained outside the firm -- the majority of these latter cases being intercorporate transfers from parent firms. This difference also holds by industry (with the exception of crude petroleum for which there was not enough data to construct valid averages), and varies from almost 4 years for electrical industrial equipment and plastics to about 2 years for smelting and refining, and telecommunications equipment innovations.

Lag Rate by Type of Transfer

When firms get outside technology for new products and manufacturing processes, do they get it faster from affiliated corporate sources than from non-affiliated arm's-length sources?

Figure 1

Average Lag Rate -- All Innovations
(By Source of Technology and Type of Transfer)



<u>Comparison</u>	<u>Level of Significance</u>
A-B	Not Significant
C-D	.15
E-F	.05
F-H	Not Significant
I-J	Not Significant
K-M	Not Significant
L-N	.10

Figure 2

Average Lag Rate -- Telecommunications Innovations
(By Source of Technology and Type of Transfer)

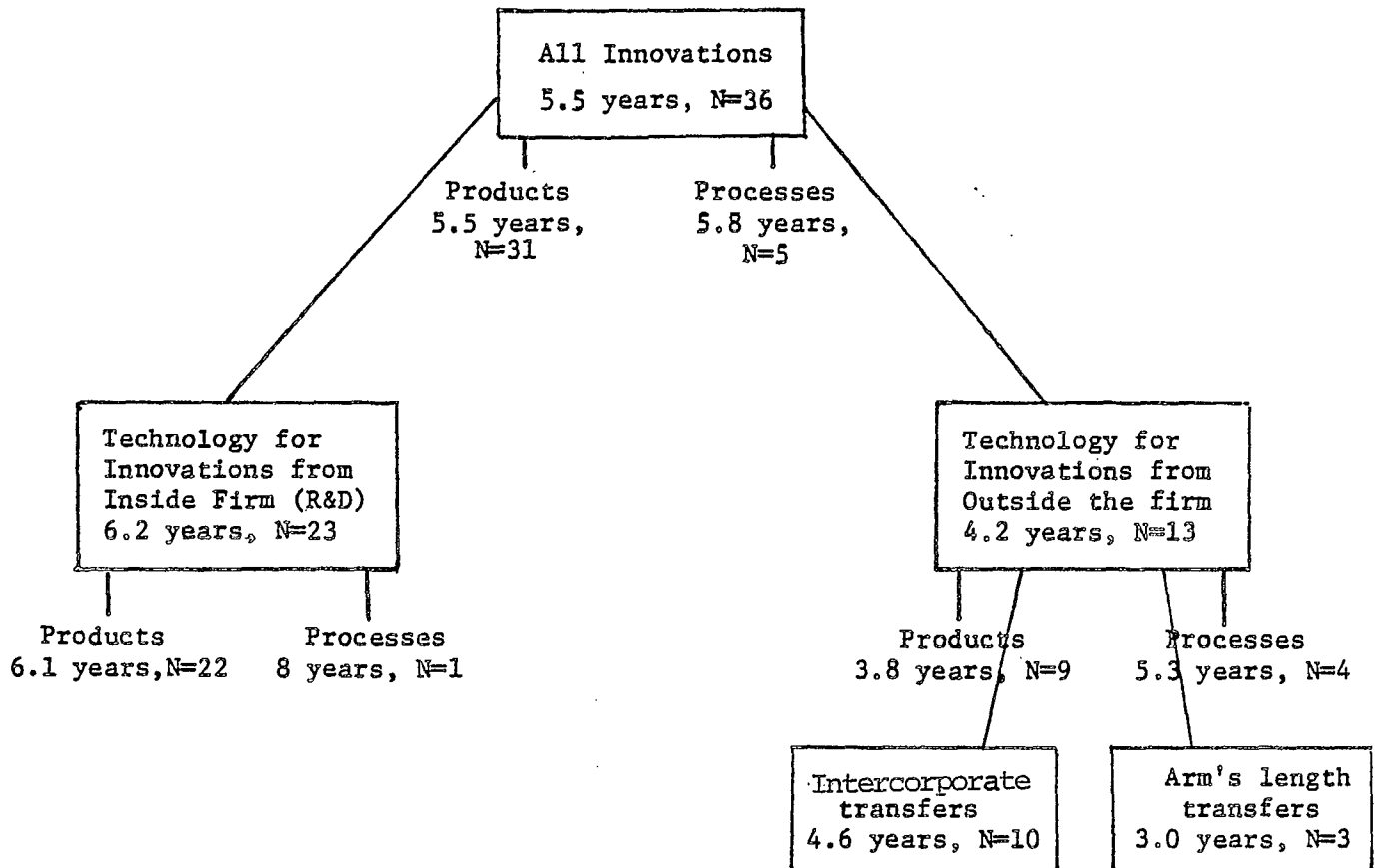


Figure 3

Average Lag Rate -- Crude Petroleum Innovations
(By Source of Technology and Type of Transfers)

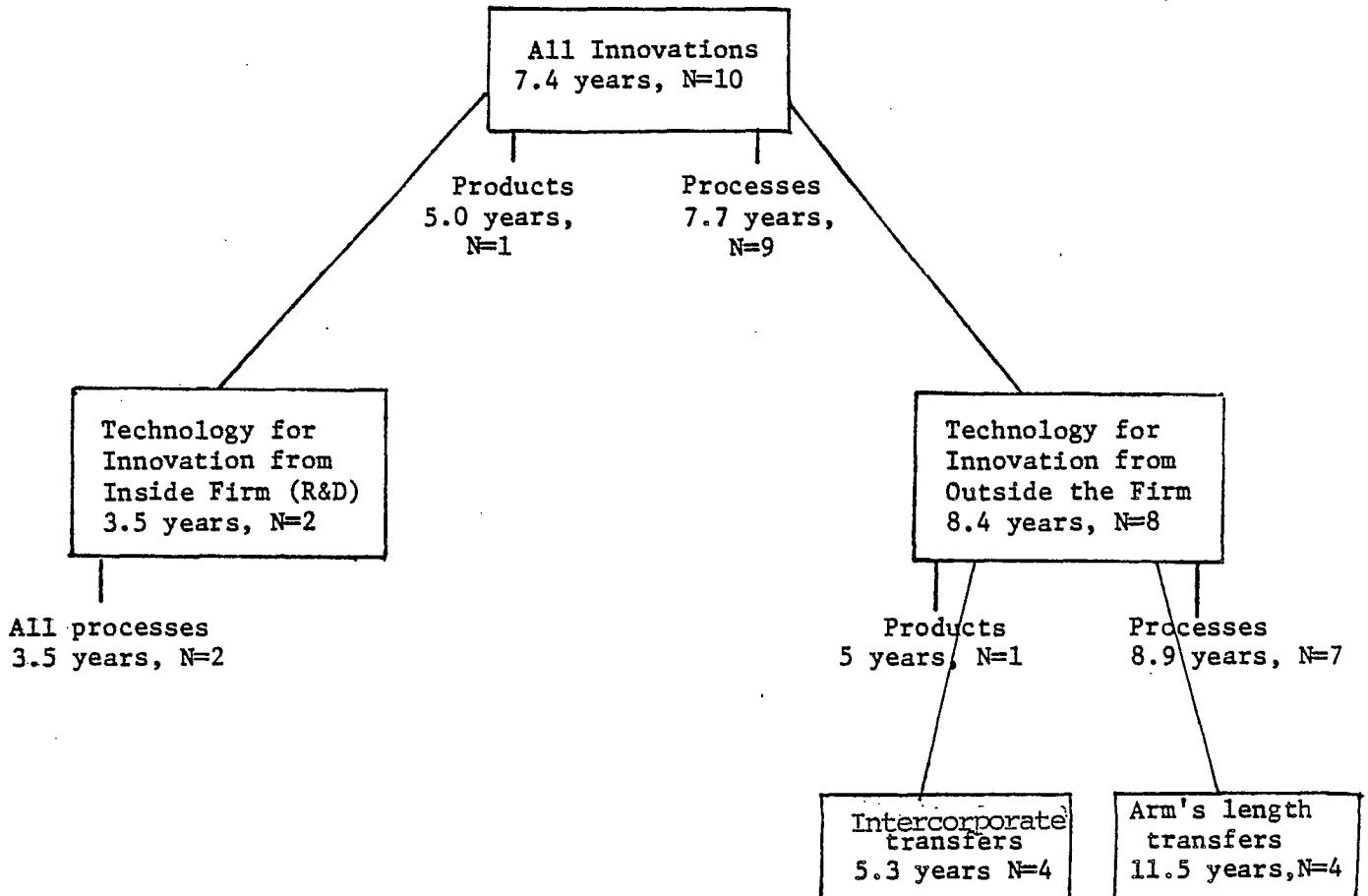


Figure 4

Average Lag Rate -- Plastics and
Synthetic Resins Innovations
(By Source of Technology and Type of Transfer)

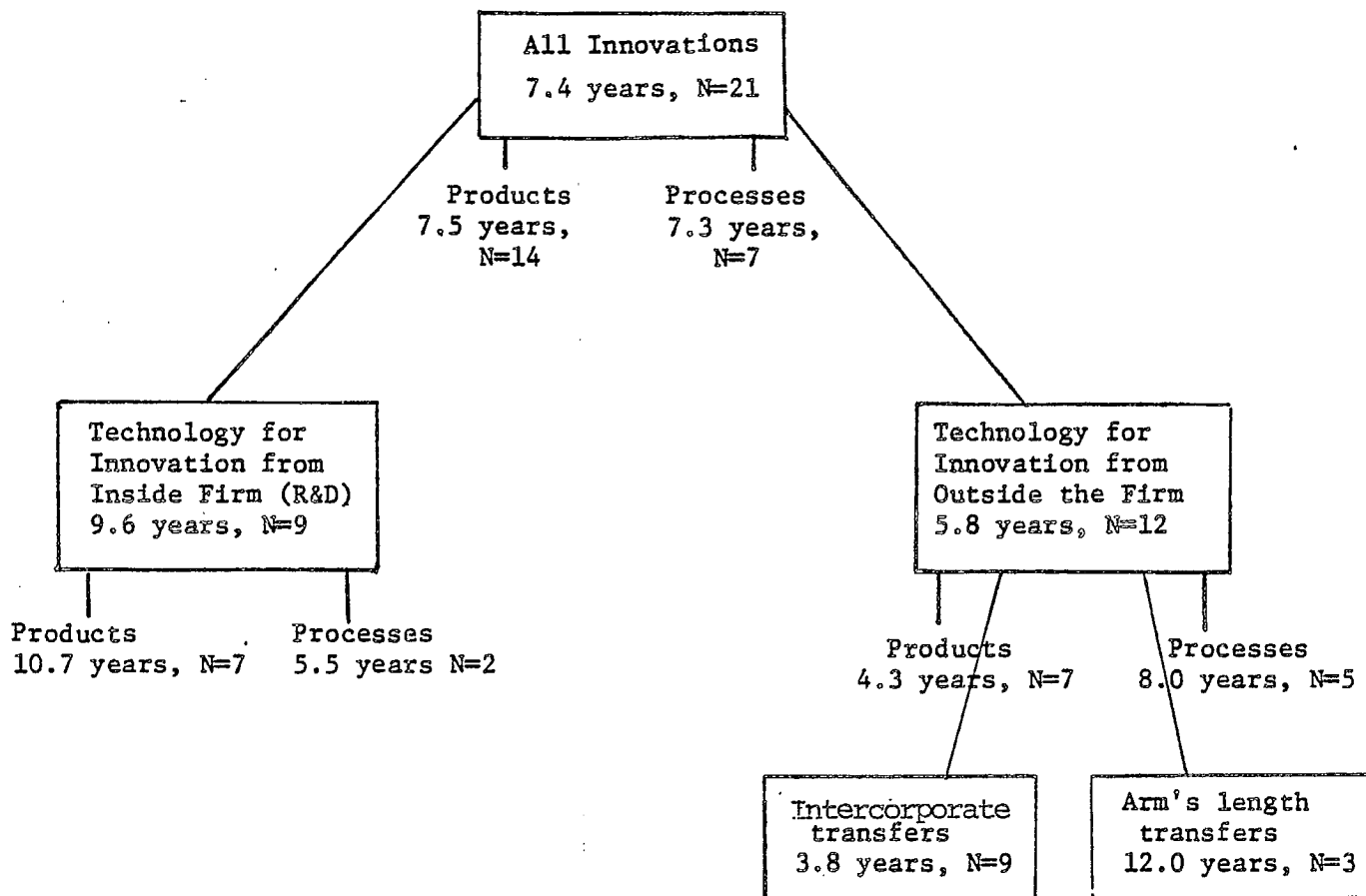


Figure 5

Average Lag Rate -- Smelting and Refining Innovations
(By Source of Technology and Type of Transfer)

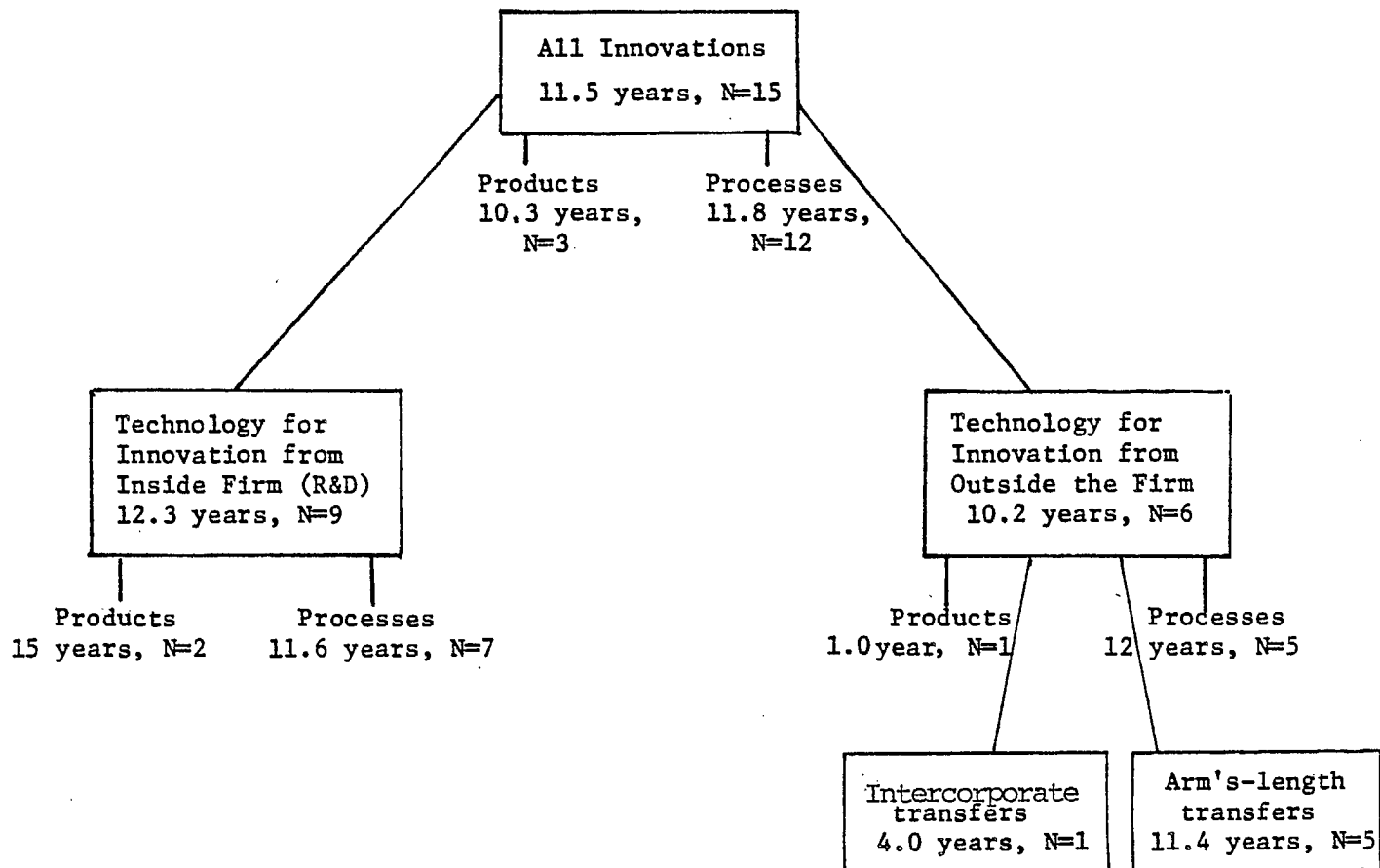
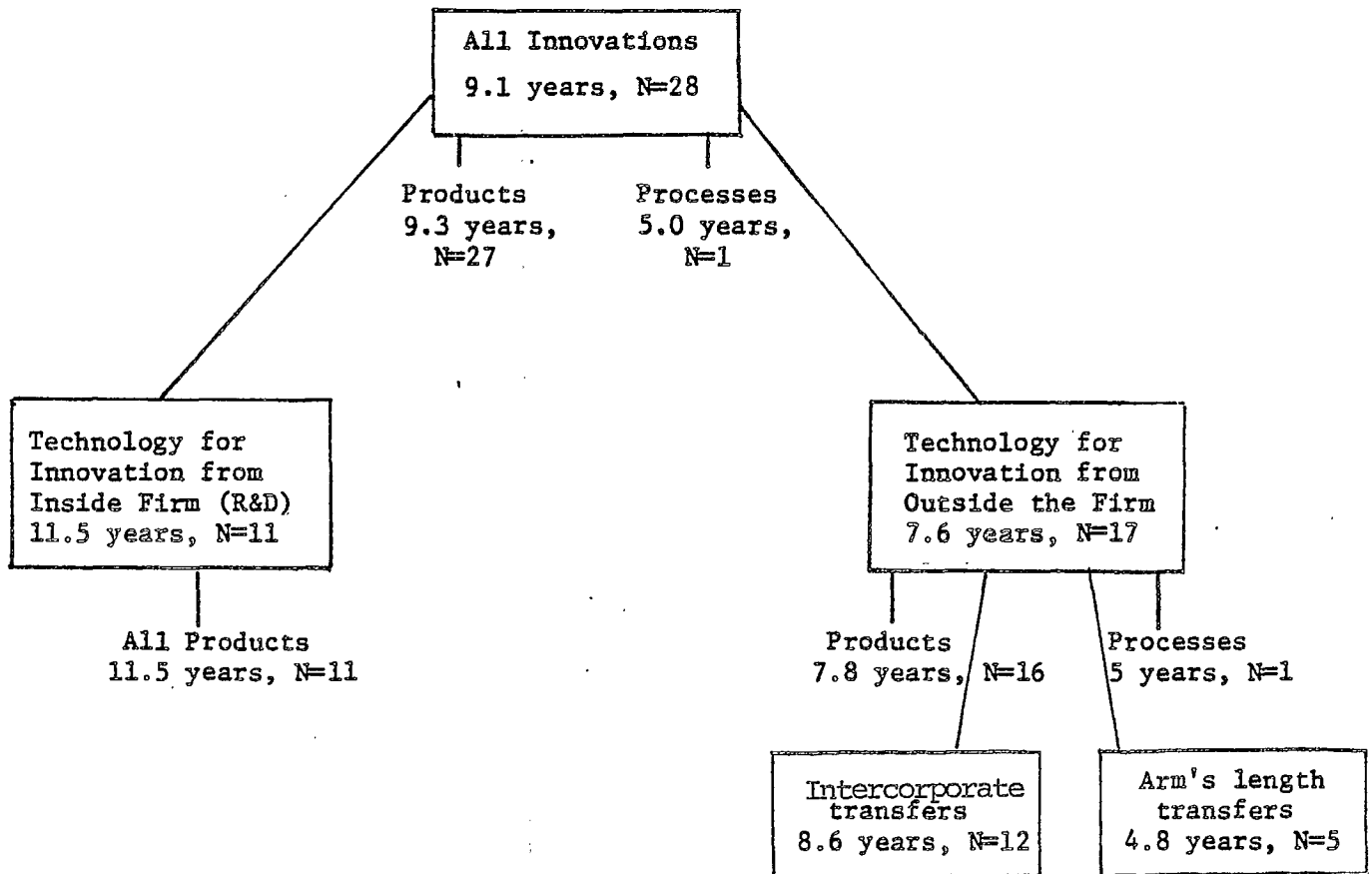


Figure 6

Average Lag Rate -- Electrical Industrial
Equipment Innovations
(By Source of Technology and Type of Transfer)



In Figure 1 the average lag rate for arm's-length transfers is not significantly shorter than the average lag rate of those cases in which the innovation was produced by the firm via research and development.

Lag Rate, by Type of Control

Do foreign-controlled firms get new technology faster than Canadian-controlled firms? In Table 1 below, the average lag rate for all innovations was 1.6 years shorter for cases associated with foreign-controlled firms. This is because one-half of the products associated with Canadian-controlled firms for which we have lag rates are in telecommunications, for which the mean lag rate is quite short. For product innovations the average lag rate was 1.2 years longer for cases associated with foreign-controlled firms although this result is not statistically significant. The average lag rate across control for production processes, was 9.4 years longer for Canadian-controlled firms. (The maximum lag rate for production processes associated with a Canadian-controlled firm was 43 years.) If we recalculate the lag rate eliminating this value -- in which case lag rates for foreign- and Canadian-controlled cases have the same range -- the mean lag rate for processes associated with Canadian-controlled firms is 6.3 years longer than processes of foreign-controlled firms.

Table 1 *

Average Lag Rate (By Type of Control)

	All Innovations	Product Innovations	Process Innovations
Foreign-controlled	7.2 years (N=72)	7.8 years (N=48)	5.9 years (N=24)
Canadian-controlled	8.8 years (N=39)	6.6 years (N=29)	15.3 years (N=10)

**Although the difference in lag rate across control for products is not significant, for processes it is significant at the .05 level.*

It is instructive to also compare how the average lag rates vary simultaneously across control and source of technology (Table 2). Do foreign-controlled firms commercialize innovations via R&D faster than Canadian-controlled firms? Do foreign-controlled firms adopt innovations and their underlying technology faster than Canadian-controlled firms?

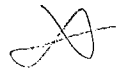
Table 2

Average Lag Rate
(By Type of Control, By Source of Technology)

	All Innovations	Product Innovations	Process Innovations
<u>Foreign-controlled</u>			
Technology via firm's R&D	8.7 years N=28	10.0 years N=21	5.0 years N=7
Technology from outside the firm	6.2 years N=44	6.1 years N=27	6.3 years N=17
<u>Canadian-controlled</u>			
Technology via firm's R&D	8.7 years N=27	7.4 years N=22	14.4 years N=5
Technology from outside the firm	9.1 years N=12	4.0 years N=7	16.2 years N=5

For both Canadian- and foreign-controlled firms completing the innovation via R&D in Canada, the average lag rate is, for all innovations, 8.7 years. There is no difference. With products done by imitation, Canadian-controlled firms arrive at the commercialization about $2\frac{1}{2}$ years faster after first world commercial launch or use than foreign-controlled firms, (although this result is not significant). But with production processes they are almost a decade (9.4) years behind foreign-controlled firms.

When the technology is adopted from outside the firm, for products the lags are more than 2 years shorter for Canadian-controlled firms, but again production processes are almost ten years behind foreign-controlled firms.



The Canadian-controlled firms in the population are mainly small in size. (Seventy per cent of these have less than 100 employees; 23 per cent have 101 to 500 employees, and only 7 per cent have more than 500 employees.) The foreign-controlled firms in the population are mainly large. (Thirty-six per cent have less than 100 employees, while 43 per cent have between 101 and 500 employees, and 21 per cent have more than 500 employees.) To eliminate variations in lag rate across control due to firm size, we also examined the average lag rates simultaneously across size and control in Table 3 below.

Table 3
Average Lag Rate
(By Size, by Type of Control)

Firm Size	Foreign- Controlled	Canadian- Controlled
Small (0-100 employees)	6.7 years (N=18)	8.8 years (N=24)
Medium (101-500 employees)	7.7 years (N=34)	10.2 years (N=10)
Large (greater than 500 employees)	7.3 years (N=18)	7.5 years (N=4)

Although there are not enough large Canadian-controlled firms for statistical purposes, with small and medium-sized firms, the average lag rate is 2 to 2½ years less for foreign-controlled firms, and this difference disappears as firm size increases.

The size categories utilized in Table 3 are standard categories for international comparative purposes. We also examined variation of lag rate across control and size with a dual-size category. In Table 4 below, small firms are those having less than 100 employees in the field in 1978 or having annual sales in the field in 1978 of less than two million dollars, while large firms have more than 100 employees and sales greater than 5 million dollars. With this second size definition, we still find that for all innovations, the average lag rate is about 2½ years less for cases associated with foreign-controlled firms, and that again this difference lessens as firm size increases.

Table 4

Average Lag Rate
(By Size, by Type of Control)

Type of Firm	All Innovations	I Tele- communications Equipment	II Crude Petroleum Production	III Plastics & Synthetic Resins	IV Smelting and Refining	V Electrical Industrial Equipment
<u>Canadian-Controlled Firms</u>						
Small (less than 100 employees or less than \$2 million sales)	9.6 years (N=28)	6.3 years (N=13)	15.3 years (N=3)	7.5 years (N=4)	28.5 years (N=2)	9.2 years (N=6)
Large (greater than 100 employees and more than \$5 million sales)	6.7 years (N=11)	2.8 years (N=4)	--	13.5 years (N=2)	22.0 years (N=1)	3.0 years (N=3)
<u>Foreign-Controlled Firms</u>						
Small (less than 100 employees or less than \$2 million sales)	6.9 years (N=24)	5.8 years (N=5)	5.0 years (N=3)	6.3 years (N=6)	6.5 years (N=4)	9.5 years (N=6)
Large (greater than 100 employees and more than \$5 million sales)	6.8 years (N=47)	5.4 years (N=14)	3.3 years (N=4)	6.8 years (N=9)	8.4 years (N=8)	8.5 years (N=12)

Lag Rate by Firm Size

Is there any methodical variation in lag rate across firm size? In Tables 5 and 6 we have examined average lag rates across two size categories, a graduated size category in terms of the number of employees in the field in 1978 and a dual size category in terms of both the number of employees and the firm sales in the field.**

Table 5

Average Lag Rate*
(By Size)

Firm Size	Average Lag Rate (All Innovations Together)
0-49 employees	6.1 years (N=28)
50-99 employees	5.6 years (N=10)
101-199 employees	4.7 years (N=13)
200-499 employees	5.5 years (N=25)
500 or more employees	5.8 years (N=21)

*To examine trends across size we have made the maximum lag rate 20 years, eliminating 11 cases, the largest of which was 43 years.

**"Field" means the area of specialization of the survey. A large telecommunications company might also produce in areas other than telecommunications.

Table 6
Average Lag Rate
(By Size)

Firm Size	All Innovations	I Tele- communications Equipment	II Crude Petroleum Production	III Plastics & Synthetic Resins	IV Smelting and Refining	V Electrical Industrial Equipment
<u>Small Firms</u>						
Number of employees less than 100 or field sales less than \$2 million	8.8years (N=53)	6.2years (N=18)	10.2years (N=6)	6.8years (N=10)	13.8years (N=6)	11.2years (N=13)
<u>Other Firms</u>						
Number of employees greater than 100 or field sales greater than \$2 million	6.8years (N=58)	4.8years (N=19)	3.3years (N=4)	8.0years (N=11)	9.9years (N=9)	7.4years (N=15)



The average lag rate gradually decreases with firm size until one reaches firms of about 500 or more employees, in which case it again increases. In Table 6 we again see that for all innovations together, the lag rate is significantly longer for cases associated with small firms. With the exception of plastics and synthetic resins, this latter result also holds by industry.

The empirical results of lag rate must be thus interpreted in light of a threshold effect on corporate size. Lag rates decrease with firm size, but once firms reach a certain size, around 500 members, then lag rates are no longer correlated with size.

Lag Rate by Cost

Even though our survey variables were limited, we can finally assume an interactive rather than an additive effect of the determinants of lag rates. Thus assuming that total cost is a proxy variable for a production processes' complexity, one can see in Table 7 that the more complex the process, the larger the lag rate.

Table 7
Process Lag Rates
(By Total Cost)
(Years)

Total Cost Production Process	N	Mean	Median
\$ 0 - \$ 50 000	2	1.5	1
\$ 50 001-\$ 250 000	7	8.3	4.5
\$ 250 001-\$1 000 000	3	8.3	3.5
\$1 000 001-\$5 000 000	11	10.2	7
Greater than \$5 000 000	6	15.5	9

Similarly this relationship obtains also by control (Table 8).

Table 8
Process Lag Rates
(By Total Cost, by Control)
(Years)

Canadian-controlled	N	Mean	Median
\$ 0 - \$ 250 000	4	11.3	6
\$ 250 000-\$5 000 000	4	20.3	15.5
Greater than \$5 000 000	2	26.0	26
<u>Foreign-controlled</u>			
\$ 0 - \$ 250 000	5	3.2	3
\$ 250 000-\$5 000 000	10	5.6	4
Greater than \$5 000 000	5	13.4	9

FORMS AND MECHANISMS OF TRANSFER

When firms obtain technology in the form of external know-how in each of the industries, what exactly is being exchanged? Is the firm typically receiving blue prints, prototypes, designs, patent rights, engineering specifications manuals, or what? Secondly, what mechanisms are the firms employing to obtain the technologies -- parent subsidiary transfers, imitation plus internal R&D, one-time purchases of know-how, licensing arrangements, or joint-ventures?

Telecommunications

With one telecommunications subsidiary designs for complete electronic systems are often purchased. This firm typically employs several mechanisms to obtain technology externally. Subsidiary transfers from a parent in Britain of engineering designs and parts and components have been their sole method of transfer in the past, but in recent years they diversified with respect to parts and components, purchasing PABX systems from Japan and switching equipment from the US. Imitation plus internal R&D also play a significant role, and the firm has personnel who specifically keep abreast of the relationship their customers have with other suppliers.

Another small telecommunications firm, when obtaining technology from other affiliates, typically receives software tapes, drawings, test documents, components, and environmental test results. The actual transfer of prototypes is extremely rare, but transfers may also involve purchase of components and special machinery and equipment not made in Canada. Components, in particular, are a real problem since there are few non-captive Canadian semi-conductor producers. The main source of semi-conductors for this industry is the US. In general many of the smaller telecommunication firms obtained technology merely by hiring software consultants.

With the large multinational subsidiaries, any of the designs completed at one subsidiary is almost immediately made freely available to others, the transfer consisting again of manuals, drawings, and occasionally photomasks. Personnel will be transferred on a contract basis, and although prototypes per se are not usually transferred, it is not uncommon for complete units to be purchased and drawings only provided.

Another frequent mechanism used by big multinationals is subsidiary-to-subsidary transfer. Research will first be done for the subsidiary on a contract basis at the multinational central laboratory. Licensing from unrelated firms simply does not occur much in this industry. The rapid movement of technology within telecommunications multinationals' subsidiaries

is "a mixed blessing"; its advantage lies in the fact that new technology is immediately available internationally and disadvantage in the loss of the markets when others adopt the technologies. As an example, PABX technology developed in Canada was first used in Australia.

Although licensing was not used often in this industry, in one case a medium-sized telecommunications equipment manufacturer obtained technology for a product by licence -- which usually consists of a technology package of designs and product specifications. There is almost always the usual geographical restrictions on licenses, (usually restricted to the Canadian or North American market, but normally a licensor may specify that he will license a technology for a specific geographical region). These license restrictions were not found to be reason for lack of exports in any of the industries.

Crude Petroleum Production and Exploration

In technology transfers in this industry, a firm will typically receive blue prints, designs, and technical support, but a standard restriction in continuing agreements in many parent-subsidiary transfers is that the technology may be utilized only in Canada. One large multinational subsidiary did get quite a bit of technology via licensing. They also bought proprietary knowledge on the market. One firm, for example,

bought process technology by entering a licensing agreement which gave them access for a limited time (less than a decade) to all new developments of the licensor, and they also agreed to give access to any new developments they made over the same period.

Subsidiaries in crude petroleum production frequently get technology via a common technology pool of all other subsidiaries plus the central research laboratory of the parent, and in joint ventures.

Virtually the only means of technology transfer by one medium-size oil company was joint venture arrangements for in-situ pilot projects for recovery of heavy oil. (Problems, of course, arise when one partner decides to pull out of an in-situ project, so it is mandatory to have agreements by which technology can be subsequently sold, but most technical information obtained through joint ventures is confidential and can only be used by the partners involved.)

Actually, new technology developed by Syncrude, of which there is a great deal, is mainly reserved for its own use and is not sold abroad by the Canadian firms. To be used elsewhere all consortium members have to agree. Syncrude sells some computer software abroad, but they cannot sell technology, because the process of getting all consortium members to agree on the sale is too difficult. So far, there is virtually no attempt

to do this, although Syncrude has developed more than 1,400 patents on one topic alone, oil skimmers.

Syncrude gets technology from the parents of participating subsidiaries. For example, extraction and frost treatment techniques were developed in-house, but much know-how is provided by Suncor; hydro-treating and fluid coking technology were licensed from Exxon; treatment technology is provided by Amoco and waste treatment technology by Chevron. Universities have been used infrequently, primarily for their facilities such as a wind-tunnel at the University of Alberta and the University of Saskatchewan's pumping research facilities.

With one large oil subsidiary, any hardware or software for production techniques is patented by its parent, and will necessarily have a licensing agreement or royalty payments "attached to it" if it is used by subsidiaries.

The most common method that one firm used to typically obtain technology involved parent-subsidary transfer, but they also are involved in joint ventures and an extensive use of outside consulting and research firms in Calgary and Edmonton.

In summary the primary means the oil industry uses to obtain external technology involves the parent's central research laboratory, the hiring of engineering and programming consultants, and joint-ventures arrangements.

In the latter, firms will typically receive a hundred per cent of the technological information about a particular project for about a five to ten per cent share of the cost. One result perhaps, of the joint-venture structure is that there is reduced economic incentive to do research on a recovery technique for any specific pool, since a single firm usually owns, on the average, five per cent of the interest in the joint-venture. The in-situ research is extremely expensive, since there are really no proven unique techniques for extraction, "only variations on stock procedures".

With regard to parent-subsidary tranfers, several firms obtaining exploration software and hardware specifically said that got a better deal with local suppliers then with the head research group.

Thus, when technology is received from external sources, it is frequently in the form of blue-prints or engineering and design specifications plus engineering release time. As an example, specifications for a blending pump were obtained from a foreign supplier, and in order that the processes into which the pump was incorporated could be operationalized, personnel from the parent firms' external consulting group had to be utilized. But information is also traded, almost like comic

books; one oil company traded current pilot data for their historical data about a well.

Many oil firms would like to patent more aggressively, but they can't because the extraction techniques are often stock variations of existing processes, and a specific geographical terrain may require merely a slight variation or combination of several basic processes for loosening and removing oil. Thus again in this industry, research units often performed a listening and monitoring function to keep up with new developments of competitors, since these in general were not patented.

Plastics and Synthetic Resins

Again in this industry the form of transferred technology was often designs and specifications, never prototypes, and usually involved a continuous flow of people. They seldom involved machinery and equipment. With respect to mechanisms, both one time purchase, licensing, and replication were used to obtain technology. There is a frequent buying of patent rights to products which have not yet been commercialized.

Since polyvinyl chloride is used when it is formulated with other materials, firms are continuously trying to update new formulations, and subsidiaries usually have access to their

parent's sales application labs, whose expertise is predominantly in formulations. When firms get "formulation technology", what they get is mainly formulation instructions or specifications, i.e., the equivalent of designs.

There also exists fairly continuous interchanges of engineers between the subsidiaries and the central parent laboratories.

Many parent-subsidiary transfers in this industry involve a continuous transfer agreement, with the parent and subsidiary firms jointly owning any improvements made to the technology.

Smelting and Refining

When these firms need an available technology, they sometimes purchased it through a licensing agreement. When firms do enter into such agreements, they will typically receive engineering drawings, designs, specifications, and blue prints. Continuous personnel exchange is important, and equipment and prototype transfer does not play any significant part.

Machinery and equipment is purchased on the open market, but even when process equipment is purchased abroad, it

is usually in the form of designs. The firms then build their own equipment.

In one smelting operation, in most technological exchanges the Canadian subsidiary was typically getting recipes from the parent. In two typical transfers, one involving the addition of lithium to an electrolytic bath for aluminum production, and a method for the simultaneous vertical casting of aluminum billets, the technology transferred was the same recipes. The prototypes are then constructed at the Canadian plant.

With several subsidiaries, instead of a continuing license for every new technology, a specific license agreement was required which contained no automatic renewal clauses but was periodically renegotiated to readjust the level of royalty payments to current sales. But restrictive licensing arrangements were few and focused on cases where the Canadian subsidiaries' products were identical to those of its parents.

Electrical Industrial Equipment

In this industry, typical transfers from the parent again involved design instructions. In one instance, the Canadian subsidiary was getting a parent's computer-aided-design programmes over a computer network. Most transfers involve blue

prints, designs, engineering instructions, and a continuous interchange of personnel, infrequently the transfer of operating machinery and components and equipment.

The main modes of transfers are parent-subsidary transfers, and imitation plus R&D; for example firm A could not get a certain part from the US, so firm B manufactured it and put firm A's name on it after the latter taught them how to make it.

SOURCES OF TECHNICAL INFORMATION

There are few studies in industrialized economies looking at how firms acquire information about manufacturing technology. But studies done of American firms,* Irish firms,** and of Canadian firms*** all found that the major information source of new technology of firms was direct personal contact with personnel in other industrial firms. The Canadian study also found that Canadian firms rely excessively on suppliers -- often sales agents of foreign multinationals -- as sources of technological information. Another point of commonality relates to the role of research institutes. All of the countries examined support such institutes, and none had a significant impact in any of the countries. Finally, in all of the studies documentation sources and computerized documentation institutes were found to play insignificant roles in diffusing technological information.

*T.J. Allen, "Managing the Flow of Technology," (Cambridge, Mass.: MIT Press, 1977).

**T.J. Allen, "Transferring Technology to the Firm: A Study of the Diffusion of Technology in the Irish Manufacturing Industry," Working Paper 942-77 Sloan School of Management, MIT, June 1977).

***Russel M. Wills, "Research, Development and Communication in the Canadian Economy," GAMMA, McGill University (April 1979).

Allen's study of sources of information for new technology in a stratified sample of 300 Irish manufacturing firms is of immediate relevance to the Canadian situation inasmuch as Ireland, like Canada, is characterized by a high penetration of foreign-owned multinational subsidiaries in manufacturing, and since the majority of Irish industrial firms do no or little research and development.

The 75 firms selected by Allen from his sample for preliminary analysis were mainly small in size, with only 5 firms in excess of 250 employees. (This bias was intentionally introduced because it was thought to be representative of Irish industry.)

The methodology employed was quite simple. In interviews, general managers of each firm were asked to think back over the past several years and identify what they thought were the most significant "changes in either products or production processes that had occurred within the firm". Persons involved in introducing the new products or production processes were then interviewed to learn more about the circumstances of the introduction.

With sources of ideas for the innovations, it was found that most information came through direct personal contact with personnel in foreign firms, with 59 per cent of all messages

coming from firms outside of Ireland. None of the information came from either Irish or foreign universities, and all government-sponsored research institutes accounted for less than 2 per cent of the messages. The most important information source of new technology for an Irish firm, Allen found, is a foreign company.

X One surprising result of Allen's study and of our own was that so many of the firms supplying information about new technology were apparent competitors. However, many of these competitors were outside the country, and Allen found in his interviews that most of these did not consider themselves to be competitors, since most of the Irish firms were fairly small and lacked any developed distribution networks required for penetrating foreign markets, an analogous situation to Canada.

Since many of the firms in Allen's sample were subsidiaries of foreign firms, he reasoned that such firms might be more inclined towards foreign sources of information about technology. His data presented little support for this hypothesis; In fact, he found that Irish firms obtained about 25 per cent of their ideas for new technology domestically, but that foreign subsidiaries obtained even more of their information from domestic sources.

Domestic firms, Allen found, since they are denied access to foreign technology of the parent, have basically substituted for this by direct contact with firms outside of Ireland.

In the survey, respondents were asked about sources of information used in the generation of their innovation. Possible answers were sources either inside the firm (R&D units, marketing personnel, etc.), or outside sources (suppliers, parent firm, nonaffiliated competitors, etc.). These outside sources are summarized in Table I.

Table I
Most Frequently Used Outside Information Sources
(By Control, By Product vs. Process)
All Firms

<u>Products</u>		<u>Products</u>	
<u>Canadian-Controlled</u>		<u>Foreign-Controlled</u>	
Source	(N=96)	Source	(N=105)
Customers	47 %	Customers	50 %
Suppliers	17 %	Parent or affiliate	39 %
Competitors	16 %	Competitors	15 %
<u>Processes</u>		<u>Processes</u>	
<u>Canadian-Controlled</u>		<u>Foreign-Controlled</u>	
	(N=25)	Source	(N=57)
Suppliers	32 %	Parent or affiliate	45 %
Competitors	16 %	Suppliers	28 %
Consultants	16 %	Consultants	12 %

1. Government institutes, written sources, documentation institutes and independent inventors were not significantly used by respondents either as a source of awareness knowledge for new product or production technology or as an aid in subsequent problem solving.

2. Customers were most often used as idea sources for new product technology by both foreign and Canadian controlled firms.

In this instance, amply explored by Eric von Hippel of the Sloan School of MIT*, it is often the potential customer who develops the idea for an innovation and then actively selects a manufacturer who is capable of constructing the product or process. For example, in 67 per cent of the process innovations von Hippel studied in the manufacture of semi-conductors and electronic sub-assemblies,* it was the customer who "dominated" the innovation process by recognizing a need, building a prototype, and utilizing the prototype prior to any involvement of a manufacturer.

*"Has a customer already developed your next product", Sloan Management Review, MIT, Winter, 1977, Volume 18, No. 2, p. 63; "Users as Innovators", Technology Review, Volume 80, No. 2, January 1978; "The Dominant Role of User and Semi-Conductor in Electronic Sub-Assembly Process Innovation", IEEE Transactions on Engineering Management, Volume EM-24, No. 2, May 1977; "The Dominant Role of Users in the Scientific Instrument Innovation Process", Research Policy, Volume 5, No. 3 (June 1976), pp. 212-39.

3. Again, suppliers were used as information source by small and medium sized Canadian firms statistically more than twice as often as used by small and medium sized foreign firms.

4. Small and medium sized Canadian firms used a competitor as information source twice as often as foreign-controlled firms of comparable size, and this difference was even more pronounced for manufacturing technology. In subsequent research it was found, analogous to Allen's study of Irish manufacturing, that such competitors were located outside of Canada (mainly in the U.S.) and did not consider themselves to be competing with the Canadian firms (since the latter lacked distribution and marketing networks to penetrate the US).

5. Subsidiaries, of course, often used their parent firms as sources, even subsidiaries with significant R&D facilities. Ronstadt* in studies of foreign R&D units of US multinationals found that the main reason for creating foreign R&D units was not to perform R&D but to aid in transferring technology from the parent to the subsidiary. In other words, subsidiaries' R&D units are often not really created to do R&D.

With these general results, let us now turn to information searching activities, by industry.

*Robert Ronstadt, Research and Development Abroad by US Multinationals: New York, 1977.

Telecommunications Equipment

Although a few extremely large telecommunications firms manufacturing highly specialized products did not have close ties with customers, virtually all other firms in telecommunications equipment did. Also frequently part of the R&D unit of firms serves basically as a monitoring and listening unit for designs and technologies worldwide.

When there were much informal communication between a firm's marketing and R&D personnel, there were always a contemporary knowledge of competing technology. Several telecommunications firms have formalized this interaction, since even for new minor products, people from marketing, R&D, and manufacturing, always jointly prepare product documentation.

Other searching activities in this industry involved discussions with components suppliers, and at technological trade shows.

With one small west coast microelectronics firm, the idea of a new technology was suggested by the customer, a large oil company with facilities at Cold Lake, which was considering computerizing their control of well-heads. The electronics firm realised that a product it was already manufacturing had new applications in this area.

One firm had personnel who continuously investigated published and unpublished marketing studies of all CATV multiple service operators, but even this group got their main technological information from suppliers of multinationals.

Suppliers as a source of technical information however were not monopolized by small firms in this industry, and big subsidiaries of American telecommunications firms naturally use suppliers from the Silicon Valley in addition to the central R&D labs of their parent firms.

Crude Petroleum Production and Exploration

In the oil industry arrangements to obtain technology and know-how mainly involve the parent firms via general technical service arrangements between the parent and all subsidiaries, and yearly preparation of the inter-corporate work plan by engineers and executives from the parent and subsidiary. As part of the general technical arrangements, there is frequently personnel exchange between a subsidiary and the large centralized R&D facilities; for example, many of the parents' exploratory units do frequently software consulting for the Canadian subsidiaries.

Just as in telecommunications, innovative firms which quickly became aware of and evaluated new technologies had continuous interactions between managerial and technical personnel. In one foreign-owned subsidiary, management were all in their late 20s or early 30s; all had a high-level of technical education before becoming managers and interacted frequently and informally about specific new extraction techniques.

Several oil companies receive much technical information by simply contracting out virtually all technical operations to local consultants, suppliers, and engineering firms. Especially critical in this area is computer modelling of reservoirs and seismic processing of data.

Joint ventures are also extremely important vehicles in exchanging technical information, since firms frequently get access to each other's research "parenthetically", as a by-product of the joint venture which is formed for control of land.

Since it may require years to determine whether a production process for enhanced recovery works even on a small scale, most pilot projects are run in the oil industry on a joint-venture basis, and automatic transfer of technological information between firms occurs.

In this context, the Alberta Oil Sands Technology Research Authority (AOSTRA) must be mentioned. Its purpose is to diffuse technology and promote research and development in heavy oil and enhanced recovery techniques. They have been endowed with \$250 million, the bulk of which is spent in field pilots involving a 50-50 per cent split between oil companies and AOSTRA, which owns the proprietary technology in these pilot plants and is the exclusive licensing agent in Canada. The income from such licensing agreements is divided equally amongst the participants. Certainly portions of the in-situ pilots should qualify under R&D tax incentives, but the oil companies are not that concerned that they get R&D tax write-offs covering "in situ pilots", as long as there is stability of rules, even for a short time, a year or two for planning purposes.

AOSTRA is also involved in several heavy oil upgrading development projects. They are also involved in several schemes to treat tailings so that they will settle more quickly and have several university research projects.

But on the university side, they have had problems making the information available to industry. Until recently there was a six-month secret period during which only firms sponsoring the university research had access to its data (after which AOSTRA owned all patents). But on April 16, 1980,

companies no longer must pay 25 per cent of the development costs for ongoing access to the technical information, but now pay only 5 per cent.

On the upgrading side, with the Alberta Research Council, the costs are treated in the same manner as any other university project, that is, 25 per cent. The secrecy rules are more strict here because they involve upgrading technology, and these techniques are more valuable in the oil industry than exploration/seismic techniques, because when such a process is offered, the guarantee of a certain level of production is involved.

One of the most significant roles of AOSTRA has been to disseminate reservoir recovery data. AOSTRA tries to develop mechanisms to disseminate (to companies which are not members of joint ventures), technical information involved in various phases of the recovery process. They jointly own, with the originating firm, all improvements made to technology in all joint ventures to which AOSTRA is a party. The oil firms themselves report AOSTRA in very favourable terms as being reliable, first of all by always having enough funds to complete projects, thus providing support research for all in situ pilots.

Finally, informal engineering information exchange in downtown Calgary is very "compact". Most management estimates that the lifetime of a new technical secret is two days to one week.

Plastic and Synthetic Resins

Technology in plastics and synthetic resins is complex and changing rapidly, and this industry also stressed the close interaction with customers both for new development needs and more often for incremental manufacturing changes which could improve products. Most of the technical people kept a close eye on what competitors were doing, and when they became aware of a new development would try to have their own people duplicated it.

Again, in this industry both marketing and technological information involved a continuous interaction with users, and with consulting engineers who are hired on a contractual basis. Since most R&D effort is concerned in process improvement, there is much interaction between research, marketing and production personnel.

Smelting and Refining

In this industry, one of the most important means of obtaining new technologies involves interaction with customers and other industry personnel in the form of plant visits.

Refining companies are remarkably free in exchanging visitors. Because ores from different locations tend to present different problems, the firms are not giving away much when competitors view their processes for that region. Since the problems tend to be somewhat unique, there is a remarkable lack of secrecy.

In one case, an aluminum smelter is purchasing a packaged CAD/CAM pollution control system for about \$100 million. Personnel became aware of this technology via corporate visits to Japan.

Some firms have personnel who only attended conferences to learn about new techniques for smelting and in several firms R&D personnel also attended the industry conferences of their major customers.

Electrical Industrial Equipment

Again close relationships with customers are critical in this industry, and innovations tend to be spontaneous upon customers' requests.

LICENSING TO CANADA

Just because a firm manufactures abroad does not necessarily imply the real transfer of the proprietary technology for manufacturing.

Given the increasing importance of semi-conductor manufacturing technology in virtually all industries, the lack of Canadian licensing data in this area and the fact that the US is Canada's predominate source of external semi-conductor technology, it is instructive to examine results of licensing studies of U.S. semi-conductor manufacturers.

Finan* has examined licensing in Britain's semi-conductor industry from the perspective the licensing American companies, and Lake** examined the same process from the perspective of the licensees.

*William Finan, "The International Transfer of Semi-conductor Technology Through US Based Firms," The National Bureau of Economic Research, New York, 1975.

**Arthur Lake, "Transnational Activity and Market Entry in the Semi-Conductor Industry", National Bureau of Economic Research Incorporated, New York, Working Paper No. 126, prepared for the National Science Foundation, Washington, D.C., March 1976.

*
Finan found that American semi-conductor companies don't consider licensing to be a major means of transferring technology to unaffiliated foreign firms. U.S. firms simply didn't wish to give foreign firms access to their most advanced technology, the only exception to this being the practice of "second source agreements", to widen a specific market for products by assuring customers that they don't have to be dependent on merely one source. Most firms in his sample did not license.

Lake found that virtually all British firms in the semi-conductor industry depended to some extent on the buying of know-how from American firms through licensing agreements, but even with firms utilizing U.S. licenses for new technology, the time lag between the first US production and the introduction of a product incorporating the new technology in the U.K. for the average licensee was greater than three years.

Finan found that US semi-conductor manufacturers grant basically two types of licenses, the first being patent licenses, which give a licensee rights to use specific patents of the licensor and involve merely legal recognition of the patent claim and sometimes royalty income. The second type of license "which ... like the patent licence grants legal permission to a licensee to utilise patents of the licensor" also provides technological assistance which usually comes in the form of engineering visits.

The most prevalent form of licenses which Finan found was patent licenses, which normally don't convey technological know-how, since in most cases firms receiving a patent are already utilising technology covered by the patent and are only trying to avoid court litigation over patent infringements. Large firms tended to be patent licensors most frequently because of their strong technological positions, and Texas Instruments, Western Electric and Fairchild, dominated the early patent license market for semi-conductors.* Royalty rates charged by these firms depended on 1) the number of patents covering the license agreement, 2) the technological capabilities of the licensee - firms with strong R&D capabilities often receive royalty-free licenses since a licensor in a cross license agreement gets the use of any licensee's patented technology, and 3) the licensor's licensing competition.

The second class of license distinguished by Finan involved direct and usually continuous technological assistance. Examples of this class of license are second-source agreements and know-how licenses. It is generally assumed by industry that any manufacturer who possesses the requisite process technology can imitate a new semi-conductor innovation within six months to a year after its initial introduction, and second sourcing is related to imitation. Finan defines second sourcing as the

*Finan, op. cit., p. 41.

"manufacture by any firm of a device which has identical specifications and which is directly interchangeable with the device first produced by the pioneering firm. Second sourcing differs from imitation in that imitators adopt the innovation but do not duplicate the innovator's product exactly; second sourcing also involves the co-operation of the pioneering firm."*

There are other differences between these two types of licenses. Second sources pertain predominantly to product technology, while know-how licenses deal with process technology. Since new production processes are frequently unstable, know-how licenses are not granted for the most advanced process technology. Finan found that US firms "mainly see licensing as either a means of avoiding costly litigation or as an opportunity to capitalize on their know-how in one-time sales to foreign firms"*.

Multinational Licensing Trends

Vernon and Davidson also examined licensing. For 32 of their firms, the authors were able to obtain data on licensing agreements with independent foreign firms. This data is contained in Table 1.

*Ibid., p. 53.

Table 1.*

Transfers of 221 Innovations by 32 Multinational Enterprises
to their Foreign Manufacturing Subsidiaries and
Independent Licensees, Classified by
Period of U.S. Introduction

	Transfers, by number of years following U.S. introduction					
Period of U.S. introduction	Same year or 1 year after	2 or 3 years after	4 or 5 years after	6 to 9 years after	10 or more years after	Total
<u>1945-1955</u> <u>(94 innovations)</u>						
Via subsidiaries	14	18	11	43	233	319
Via licensees	1	9	28	16	92	146
Subsidiaries as % of total	93.3%	66.7%	28.2%	72.9%	71.7%	68.6%
<u>1956-1965</u> <u>(70 innovations)</u>						
Via subsidiaries	24	39	21	46	49	179
Via licensees	7	10	15	13	22	67
Subsidiaries as % of total	77.4%	79.6%	58.3%	78.0%	69.0%	72.8%
<u>1966-1975</u> <u>(57 innovations)</u>						
Via subsidiaries	22	37	21	16	1	97
Via licensees	2	4	10	6	2	24
Subsidiaries as % of total	97.7%	90.2%	67.7%	72.7%	33.3%	80.2%
<u>Total, 1945-1975</u> <u>(221 innovations)</u>						
Via subsidiaries	60	94	53	105	283	595
Via licensees	10	23	53	35	116	237
Subsidiaries as % of total	85.7%	80.3%	50.0%	75.0%	70.9%	71.5%

*Source Vernon and Davidson, op. cit., p. 63.

Table 2*

Transfers of 359 Imitations by 32 U.S.-Based
Multinational Enterprises to their Foreign
Manufacturing Subsidiaries and Independent
Licensees, Classified by Period
of U.S. Introduction

Transfers, by number of years following U.S. introduction						
Period of U.S. introduction	Same year or 1 year after	2 or 3 years after	4 or 5 years after	6 to 9 years after	10 or more years after	Total
<u>1945-1955</u> (120 imitations)						
Via subsidiaries	4	24	23	53	272	376
Via licensees	4	5	6	25	101	141
Subsidiaries as % of total	50.0%	82.8%	79.3%	67.9%	72.9%	72.7%
<u>1956-1965</u> (140 imitations)						
Via subsidiaries	36	50	43	83	89	301
Via licensees	7	25	9	21	19	81
Subsidiaries as % of total	83.7%	66.7%	82.7%	79.8%	82.4%	78.8%
<u>1966-1975</u> (99 imitations)						
Via subsidiaries	53	21	10	9	1	94
Via licensees	6	10	2	0	0	18
Subsidiaries as % of total	89.8%	67.7%	83.3%	100.0%	100.0%	83.9%
<u>Total, 1945-1975</u> (359 imitations)						
Via subsidiaries	93	95	76	145	362	771
Via licensees	17	40	17	46	120	240
Subsidiaries as % of total	84.5%	70.3%	81.7%	75.9%	75.1%	76.3%

* Source Vernon and Davidson, op. cit., p. 69.

Over the course of time the relative importance of licensing is decreasing, from, for example, 31.4 per cent of transfers in the 1945 to 1955 period to 19.8 per cent between 1966 and 1975. Vernon and Davidson were also able to collect similar data for imitations (Table 2). Here they found obvious similarities. With imitations, like innovations, firms over time are more frequently utilising subsidiaries than licensees to transfer production technology overseas. "Indeed the preference for subsidiaries was even more pronounced in the transfer of imitations than in the innovations data. The imitations data parallel the innovations in still another aspect; the dominance of subsidiaries over licensees is strongest amongst the more recent imitations, those introduced between 1965 and 1975."*

The most comprehensive study of manufacturing under license in Canada was made by John Peter Killing.** Examining only the mainly Canadian-owned secondary manufacturing sector, Killing set forth to determine whether licensing was a possible strategy for growth, and whether or not it was a real alternative to in-house R&D. Killing found that what he called "research-oriented firms" often obtained licenses for products early in their life cycle and did not face export restrictions

*Vernon and Davidson op. cit., p. 68.

**John Peter Killing, "Manufacturing Under License in Canada", Technological Innovation Studies Program Research Report, Department of Industry, Trade and Commerce, February, 1975.

on these licenses. He concluded that although manufacturing under a license provides a continuous flow of technology for firms which don't have an R&D capability, it's not a good strategy for long-term growth.

Much of Killing's work is based on Crookell,* who had found that "Canadian-owned firms, securing technology through license agreements, may be more constrained by and dependent upon their licenses, than foreign subsidiaries are on their parents".**

In Crookell's work, three types of licensing agreements were distinguished - those giving access to all technology present and future of the licensor, those giving access to all technology then in place of the licensor, and licenses for specific patented processes and products. Crookell found that Canadian-owned firms using the first type of license never developed much technological capability and remained dependent on the licensor.

Killing initially tried to determine the conditions under which Canadian-controlled firms license. Prior to the third quarter of 1973, during which the Statistics Canada "Balance of Payments Reports" first came out, there were no data available in Canada on the extent of licensing. In this 1973 report the average payment per license to Canadian-controlled licensees was \$12,568 while the average payment per license to

* Crookell, "The Transmission of Technology Across National Boundaries", The Business Quarterly, Autumn 1973.

**Ibid., p. 52.

U.S. controlled licensees was \$52,357. At that time then the initial evidence was that Canadian-controlled firms had agreements with much lower royalty rates than either U.S. controlled or U.K. controlled licensees. It should be noted that all of Killing's licensees were Canadian controlled, and he paid no attention to parent-subsidiary licenses. Killing examined only arms length licenses which he basically thought of as being the purchase of the results of R&D.

Killing found that almost half of the licensees with license agreements which allowed them to export took no advantage of this opportunity.*

The Grey Report, examining 208 license agreements between 1965 and 1969, found that only 5 per cent of the agreements did not contain export restrictions, but the Statistics Canada Balance of Payments 1973 data found that 35 per cent of 3417 license agreements contained no export restrictions in 1972 and that 48 per cent of these restricted the licensee to Canada. For Canadian-controlled firms, 63 per cent of the agreements allowed exports to virtually all countries, with only 24 per cent restricting the licensee to Canada.

With respect to restrictions, Killing found that 60 per cent of the license agreements in his survey prevented the licensees from exporting from Canada,** a real discrepancy with

*Killing, op.cit., p. 37.

**Killing, op. cit., p. 113.

Statistics Canada data. He also found "When technical know-how is included, (in the license) export restrictions are more frequent and most frequent when that know-how is provided on a continuing basis."*

In 80 per cent of his continuing transfer agreements that were entered by firms with a low in-house research and development capability, licensees were restricted to selling products made under license on the Canadian market.

There is, then, conflicting data on both the extent of licensing and the presence and effects of restrictions.

In our sample of 283 of the most profitable products and manufacturing processes introduced by the firms, licensing was not found to be a significant means of obtaining technology, occurring in 29 (10 %) of the 283 innovations, and five of these were incidental licenses and did not involve the primary source of the innovations' technology. These 29 innovations in which technology was licensed from others accounted for less than 12 per cent of the deflated total expenditures on innovations, and had an average lag rate of more than half a decade.

*Ibid., p. 113.

About a third of the 29 licenses were associated with very large firms, with small firms comprising 27 per cent of licensees. Over half of the licensed processes were licensed by large firms, while small and medium sized firms were the predominate licensees for product technology (Table 1).

Table 1

Firm Size of Licensees
(N=29)

	Process		Product	
Small firms (0-100 emps.)	2	(22%)	6	(30%)
Medium firms (101-500 emps.)	2	(22%)	10	(50%)
Large firms (500 emps.)	5	(56%)	4	(20%)
Total	9	(100%)	20	(100%)

With respect to control, processes associated with foreign-controlled firms accounted for 89 per cent of the licensed manufacturing processes, and only one Canadian-controlled firm licensed process technology (Table 2).

Of the 17 instances of foreign-controlled licensees, 10 occurred on an intercorporate basis, while 7 were arms length. The Canadian-controlled licenses mainly occurred on an arms-length basis.

Table 2
Firm Control of Licensees
(N=29)

	All innovations		Processes		Products	
	N	%	N	%	N	%
Canadian-controlled	12	41	1	11	11	55
Foreign-controlled	17	59	8	89	9	45
Total	29	100	9	100	20	100

RESTRICTIONS ON LICENSES AND TRANSFER AGREEMENTS

In Tables 3-5, we have examined the nature of, and restrictions on, licenses and written/unwritten transfer agreements (such as general multinational agreements in which the subsidiary gains general access to the results of a parent's R&D for a yearly flat fee).

For products about half of the Canadian-controlled transfers are continuous rather than one-time, but 85 per cent of the product transfers to foreign-controlled firms are continuous.

Table 3

License and Transfer Agreements for Innovations

Nature of agreement	Products			Processes		
	Population	#	Responding Yes	Population	#	Responding Yes
Continuous	62	48	(77%)	33	21	(64%)
One-time	61	14	(23%)	33	12	(36%)
Cross-license	58	7	(12%)	30	3	(10%)
Written	61	37	(61%)	29	23	(79%)
<u>Rights and Restrictions</u>						
Specify right to manufacture	47	41	(87%)	27	14	(52%)
Specify right to sell	50	44	(88%)	28	11	(39%)
Use of trademark or name	41	28	(68%)	25	7	(28%)
Specify any territory of manufacture	57	27	(47%)	26	11	(42%)
Exclusive right to manufacture	49	31	(63%)	21	1	(5%)
Exclusive right to sell	50	29	(58%)	20	1	(5%)
Specify exclusive rights to improvements	54	7	(13%)	25	0	(0%)
Specify input sources	50	2	(40%)	25	0	(0%)

Table 4

License and Transfer Agreements for Products

Nature of agreement	Canadian			Foreign		
	Total	N	# Responding Yes	Total	N	# Responding Yes
Continuous	15		8 (53%)	47	40	(85%)
One-time	14		7 (50%)	47	7	(13%)
Cross-license	13		2 (15%)	45	5	(11%)
Written	14		13 (93%)	47	24	(51%)
<u>Rights and Restrictions</u>						
Specify right to manufacture	14		12 (86%)	33	29	(88%)
Specify right to sell	14		13 (93%)	36	31	(86%)
Use of trademark or name	11		8 (67%)	29	20	(69%)
Specify territory of manufacture Canada	15		4 (26%)	42	17	(40%)
Territory of sales Canada	15		3 (20%)	42	15	(36%)
Exclusive right to manufacture	10		7 (70%)	39	24	(62%)
Exclusive right to sell	11		7 (64%)	39	22	(56%)
Right to improvements	14		1 (7%)	40	6	(15%)
Input sources specified	13		0 (0%)	37	2	(5%)

Table 5

Licensing and Transfer Agreements for Processes

Nature of agreement	Canadian			Foreign		
	Total	N	# Responding Yes	Total	N	# Responding Yes
Continuous	5		1 (20%)	28	20	(71%)
One-time	5		4 (80%)	28	8	(29%)
Cross-license	5		0 (0%)	25	3	(12%)
Written	5		3 (60%)	24	20	(83%)
<u>Rights and Restrictions</u>						
Specify right to manufacture	4		2 (50%)	23	12	(52%)
Specify right to sell	4		2 (50%)	24	9	(38%)
Use of trademark or name	4		0 (0%)	21	7	(33%)
Specify territory of manufacture Canada	4		0 (0%)	22	8	(36%)
Territory of sales Canada	4		0 (0%)	28	4	(15%)
Exclusive right to manufacture	3		0 (0%)	18	1	(6%)
Exclusive right to sell	3		0 (0%)	17	1	(6%)
Right to improvements	4		0 (0%)	21	0	(0%)
Input sources specified	3		0 (0%)	22	0	(0%)

Although almost all of the product agreements with Canadian-controlled firms were written, only about half of the product agreements with foreign-controlled firms were written, and a slightly higher median payment for technology was found for such unwritten agreements (Table 6).

Table 6
Payments for Technology to the End of 1978
(N=48)

Type of agreement	N	Mean	Median
Written	34	\$994 218	\$145 000
Unwritten	14	\$210 000	\$165 000

There were, however, no significant differences in restrictions between written and unwritten agreements.

With respect to licensing rights such as the right to manufacture or sell the product, exclusive rights for manufacturing and sales, and the use of a trademark or name, there is not much difference between foreign and Canadian-controlled firms. But in 15 per cent of the foreign-controlled cases, the licensor exclusively owned all improvements the recipient made to the product technology, while such was the case for only one Canadian-controlled firm.

When we look at specific territorial restrictions, 26 per cent of the agreements with Canadian-controlled firms for products are restricted to manufacturing in Canada, while 40 per cent of foreign-controlled agreements for products are restricted to manufacturing in Canada.

With respect to territorial restrictions on sales, this difference across control is more pronounced. Twenty per cent of the Canadian-controlled product agreements restrict sales to Canada, but 36 per cent of the agreements with foreign-controlled firms for product technology restricted sales to Canada.

Turning now to manufacturing processes, although our numbers are small, it is clear that agreements with Canadian-controlled firms for processes were mainly one-time, while subsidiary agreements were continuous in some 71 per cent of the respective cases. There were no cross licenses for process technology by Canadian-controlled firms and only ten cases of process technology transferred to Canadian-controlled firms. Of these, none of the agreements specified the territory of manufacture under the process, gave exclusive rights to manufacture under the process, exclusive rights to sell, specified sources of input or gave improvements rights the Canadian firms made in the process to the source firm.

With agreements and licenses of foreign subsidiaries, the use of a trademark or name was transferred in a third of the agreements for process technology, and the territory of manufacture by foreign subsidiaries was restricted to Canada in over a third of the respective cases. The territory of sales using process technology for foreign-controlled firms was restricted to Canada in only 15 per cent of the respective cases.

Significantly the specification of input sources and reservation of improvement rights were not present in any agreements for process technology by foreign-controlled subsidiaries located in Canada.

LICENSING AND SALES FROM CANADA

In terms of the reverse direction, to what extent do Canadian firms license technology to others?

In telecommunications equipment and components, some Canadian firms do license technology to other countries and firms on a limited extent. One firm, for example, currently has such an agreement with a Japanese firm, but such licensing was done not to achieve direct sales for the use of the technology, but in order to enter a market to which the Japanese government will not otherwise allow imports.

Other telecommunications equipment firms licensed technologies which they had developed in joint ventures in third world countries. They usually entered these joint ventures as minority partners to gain access to marketing information and to cultural ties.

In crude petroleum production, with the peculiar joint venture structure involved in "in-situ" pilots, technical information of US and British parents of joint venture partners is sold to a joint venture consortium such as Syncrude.

In smelting and refining, most firms did not sell or license much technology. They simply did not regard licensing of technology as a significant money maker. Firms that did license technology basically had a defensive patent policy. Even large Canadian smelting firms have not sold or licensed much technology but are presently quite keen on so doing, especially for exploration, mining and process technology. When smelting and refining firms do license out technology, which they have in several past instances, they might charge a straight fee for design of the process plus a payment for the first three of four years the process is operational, based on the output volume. Whenever a firm licenses out process technology for real use, however, they must have engineers available for release time to

implement it. There is a widespread scarcity of process engineers in this industry.

In electrical industrial equipment, with most large Canadian firms licensing of technology is almost negligible. Some firms, however, have licensed technology in the developing world.

In plastics and synthetic resins, firms felt that it was better to export than license, if that was possible, and did not do much licensing to others outside of cross licenses with the parent firm. Another firm, however, did sell technology, primarily by license, aggressively pursuing sales of agricultural chemicals in Asian and African markets.

In all the industries then, of 283 innovations, 41 (15 %) had associated technology licensed or sold in the reverse direction -- from Canada to other countries and firms.

Of these 41, about a third (37 %) were for processes and about two-thirds (63 %) were for products (Table 1).

Table 1
Firm Control of Licensers
(N=41)

	Products		Processes	
	N	%	N	%
Canadian-controlled	13	50	4	27
Foreign-controlled	13	50	11	73
Total	26	100	15	100

With regards to control, 59 per cent of the export licensing or sales was done by foreign-controlled subsidiaries, and subsidiaries were responsible for 73 per cent of the licensing or sales of process technology from Canada.

Table 2
Firm Size of Licensers
(N=37)

	Canadian-controlled		Foreign-controlled	
Small firms (0-100 emps.)	9	(69%)	3	(13%)
Medium firms (101-500 emps.)	4	(31%)	11	(46%)
Large firms (500 emps.)	0	(0%)	10	(41%)
Total	13	(100%)	24	(100%)

With respect to firm size (Table 2), most of the foreign-controlled licensers were large, but 69 per cent of the Canadian-controlled licensers were very small firms, of less than one hundred employees. However many small firms interviewed

generally felt that licensing technology to others was unprofitable because the high marginal costs (associated with engineering release time) that are incurred to support know-how agreements exceeded potential income. Each time technology is licensed to a foreign firm, there must be engineers available to implement it. Again Canadian firms don't have engineering and software people available for release time to work on such implementations. Related to this point, Tilton* found that significant factors accounting in part for foreign firms' unwillingness to react as rapidly to changes in market conditions as American firms were a lack of venture capital to encourage new firm formation and a real limited mobility of engineering personnel.

Finally we have examined the source of technology for licensors (Table 3). Innovations based on in-house R&D rather than on external technology accounted for 85 per cent of the product sales and licenses, and 73 per cent of the instances of sales and licensing of processes from Canada.

Table 3
Sources of Technology of Licensors
(N=41)

	Products		Processes	
	N	%	N	%
Technology from outside	4	15	4	27
R&D	22	85	11	73
Total	26	100	15	100

*John Tilton, International Diffusion of Technology, The Case of Semiconductors, (Washington, DC, The Brookings Institute, 1971).

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