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TECHNOLOGICAL INTENSITY:

Concepts and Measurement

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EXECUTIVE SUMMARY

This study aims to provide a more adequate conceptual and statistical definition of technological intensity (TI) than is currently in general usage. It argues that the mass media and public policy notion that TI is equivalent to R&D intensity generated strictly within the sector considered is flawed and can give rise to ill-advised support policies to technology.

Rather -- it is suggested with strong statistical back-up -- a given SIC industry's technology consists of the following components: own-performed or direct R&D, free access to research results of foreign affiliates, intramural research by government which is assignable to the industry, and equally assignable university research. These components make up an "own-intensity" TI which is based on research activities undertaken directly for the benefit of the sector considered. It would not be foolhardy to suggest that at least in those Canadian sectors in which there is considerable foreign ownership, this more encompassing definition would yield double or more the intensity based solely on direct research.

"Total-output-content" of R&D is another concept of TI considered. It incorporates all the previous components plus research undertaken by the industry's suppliers and gives an inkling of the technical sophistication of the industry's output rather than of its own activities. Recent work at the Economic Council and elsewhere shows that R&D embodied in supplies may represent a substantial proportion of an industry's TI under the "content" definition.

It is concluded that more careful diagnostic effort is required with respect to judging an industry's technological intensity before support is committed at all to further stimulation of it; and that a component-by-component appraisal will facilitate the targeting of such support. Last but not least, this study provides what is likely to be the first estimates of government intramural and university research performed for the benefit of specific SIC sectors.

INTRODUCTION

The concept of technological intensity (TI) and of its extreme version, high technology, has imprinted itself firmly on public awareness and has a subtle impact on public policies; even the ever-skeptical economists have not escaped the popular attraction of it. Firms and industries bearing the happy sobriquet "hi-tech" are deemed virtuous and often deserving of direct or indirect subsidy for it is feared that if left alone, they could underinvest in technology and thus not benefit themselves and the rest of the economy as much as would be warranted.

Yet upon reflection it becomes clear that there are at least two plausible versions of the concept of TI, each with its own definitional difficulties and different implications. This is an investigation -- perhaps pilot essay would be a more appropriate designation -- into the meaning, validity and usefulness of the concept and its two versions. Perhaps more fundamentally, this is an enquiry into the feasibility of a satisfactory statistical definition of the TI concept itself.

Meaning - In my opinion there are at least two plausible sets of meanings attached to the concept of TI.

The first considers, in its most primitive version, the technology - generating <u>activities</u>, typically R & D outlays, of the firm or of the industry alone, whether own-performed or contracted out. More elaborate versions would take into account global research and technological activities of the affiliates of foreign-owned subsidiaries in a given

Canadian sector and government and university research assignable to the firm or industry. The monetary value of such activities would then be divided by output in order to make intersectoral comparisons possible.

The second set of meanings, again stretching from simple to elaborate versions, refers to the technological content of the firm's or of the industry's output. This content is generated by one or all of the activities already mentioned plus the research effort of first - or higher - round suppliers.

Both concepts of the TI share many identical "components" which should be taken into account when attempting a satisfactory definition. Some of these components have not received much attention in the literature and are not easy to estimate. The following figure attempts to present the two alternative sets of meaning that can be given to TI in a summary form.

FIGURE 1

Two Versions of Technological Intensity

(R & D Outlays/Output)

Own Intensity — Output Content Intensity

R & D performed intramurally or funded by industry

Invisible R & D imports by foreign-owned subsidiaries

Government intramural R & D assignable to industry

University research assignable to industry

Commercial suppliers' R&D - first upstream level

Suppliers' R & D - "cycled"
- domestic suppliers
- foreign suppliers

Validity - the principal effort of this study is directed to the valid definition of either of these two versions of the concept of TI. On my interpretation a valid definition is one which comes as close as possible to the proposed concept of TI yet is operationally attainable with existing statistical data. An example of the process of reaching definitional validity is, for instance, the attempt to assign at least some of a government ministry's intramural research outlays to the specific industry being examined.

Usefulness - The two concepts may have uses in different settings. It is likely that they would be of greater relevance to public policy issues than to private decisions. For instance, in these times of abundant R & D subsidization by taxpayers, support to innovation-creating efforts might be channelled with preference to those industries which are deemed technology-intensive under the "own-activity" or "own-intensity" definition. Subsidization of innovations' diffusion, on the other hand, could be directed to industries considered technology-intensive under the "output content" definition since they could prove to be particularly receptive to innovations. As another example, the picture usually presented of Canada's poor performance in technology-intensive product exports may be substantially modified if the "advanced" versions of one or the other definitions are resorted to.

The principal practical goal of this study is, however, wider: it is to show that the concept of "high-tech" is not self-evident and that it is in the interest of public funding bodies and advisory councils to be more aware that plausible definitions of technological intensity are desirable, achievable and diverse.

After some hesitation, the component-by-component layout of Figure 1 was chosen as the framework of the study and of this report itself. Accordingly attention turns successively to a critical examination of each component of TI, in the order indicated in Figure 1. It was not possible to provide a complete statistical profile of each component of TI for Canadian industry, but an effort was made to furnish illustrative data for several SIC 2-or 3-digit industries. The first five chapters are devoted to the analysis of the intensity components. Chapter 6 gives an overview of the importance of the hitherto neglected components in the total picture of TI and Chapter 7 discusses some implications of the findings of this study.[1]

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[1] I would like to thank several persons who provided indispensable help in the course of this investigation, but who are of course not responsible for the errors contained in this report:

H. Stead, B. Plaus and M. Boucher of the Science and Technology Division of Statistics Canada, A. Bain of AECL, N. Tape of Agriculture Canada, S. Grimley and R. McFarlane of NRC, L. Carlson and P. Larose of Environment Canada, and Messrs. Harrison and Tardif of EMR.

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CHAPTER 1

AN INDUSTRY'S "VERY OWN" or "DIRECT" RESEARCH

General Observations

It is difficult to choose a single, pithy adjective which would express the meaning that is customarily given to this the most obvious component of an industry's technological intensity. What we have in mind is the R & D effort performed intramurally by the firms of an industry in Canada.

Consider this definition at greater length. We talk, of research performed inside the firms, or intramurally. Such research may be funded entirely by the firms themselves. It may be in part supported by government subsidies or even performed under contract to government or other third parties. No matter what the funding mix, however, it is clear that such performed research is of close relevance to the industry's productivity or revenue potential. (The same applies to research and development commissioned by the firms of the industry from other firms, universities or government laboratories extramural research. We shall sidestep extramural research, which accounts for possibly ten percent of private-sector research funds, because of the statistical difficulty of avoiding double-counting).

This "very own" research is in most instances the sole accepted, self-evident basis for the definition of research intensity. (Typically, the current R & D outlay figure is divided by current industry output or sales, for intensity is logically understood to be a percentage). The outstanding example of the use of this definition of TI is a series of MOSST working papers and Science Council of Canada publications.

It is a constant preoccupation of many Canadians that our economy appears to be one in which hewers of wood and drawers of water supply the rest of the world with low-technological-content unprocessed or semiprocessed goods while importing so-called high-technology goods. In response to this perennial preoccupation MOSST, the Ministry of State for Science and Technology, issued in July 1978 background paper No. 5 on Canadian Trade in Technology-Intensive Manufacturers, 1964-76. As expected, the paper found a growing Canadian trade deficit in those products. (For a critique of this finding see the author's Industrial Innovation, Vancouver: The Fraser Institute, 1984, ch. 5). It wrestled, however, also with the lack of agreement over which products should be considered technology-intensive.

According to the anonymous authors of the MOSST paper the attempt was "made to measure the degree of technical sophistication of products that gives them a competitive edge, either from process or product technology" (p. 7). However, the technical sophistication that Canadian logging and paper mill operations bring to our paper product exports was, for instance, not judged very high given that "very own R & D" intensity was chosen as the best proxy indicator of this technical sophistication -- and given that this direct R & D intensity in the two industries is rather low.

It is instructive to take a look at how several TI measures can be derived even if only "very own R & D" is adhered to and to see some classifications of industries according to those calculated TI measures.

Detailed Definitions and Industry Classifications

A) Industry-based measures

As the above-mentioned MOSST paper points out, the direct R & D outlays ("very own" in our definition) can be in principle obtained either on an industry or on a product basis. Industry-based R & D outlays are derived from questionnaires submitted to individual firms, with the firms being in turn classified into a 2-digit (such as chemicals) or 3-digit (such as pharmaceuticals) industry according to their main activity. A firm may thus be classified as belonging to a given industry if perhaps one-third of its activity lies in this field and its other activities are widely dispersed. Then the R & D outlays - and sometimes qualified scientific and engineering personnel - of these firms are aggregated and a total SIC (standard industrial classification) industry R & D expenditure or personnel is obtained.

The industry-based measures of TI can still differ if different denominators are employed: output, shipments or sales on one hand and value added on the other. A comparison between two measures is shown in Table 1.1; they obviously do not yield a uniform TI ranking or classification.

TABLE 1.1

Measures of Research Intensity in Four

Canadian So-called Research Intensive Industries

1973 and 1975

SIC No.	Industry	R & D/Value Added 1975	R & D/Sales 1973
16	Electrical Products	5.1	3.7
18	Petroleum & Coal Products	4.6	0.4
14	Machinery	3.2	1.3
19	Chemical Products	2.5	2.5

Sources: Table 1, R & D in Canadian and Foreign-Controlled Manufacturing Firms, MOSST Background Paper No. 9, Ottawa, 1979; Table 2 Canadian Trade in Technology - intensive Manufacturing, 1964-76, MOSST No. 5, Ottawa, July 1978.

The uses to which an industry-based measure of direct TI can be put are illustrated by the MOSST background paper No. 4, issued in July 1978 and titled Performance of Canadian Manufacturing Industries by Levels of Research Intensity. Two-digit manufacturing industries were classified by R & D/Value Added in 1974 and

"research intensive" defined as RD/VA > 3

"medium-research-intensive" defined as 1 < RD/VA < 3

"low-research-intensive" defined as RD/VA < 1

"no-research intensive" defined as RD/VA = 0

This gave the following rankings (MOSST No. 4, p. 17):

1. Research-Intensive Industries:
   Machinery Industries
   Electrical Products
   Petroleum Products

Chemicals & Chemical Products

2. Medium-Research-Intensive Industries:
   Paper and Allied Products
   Primary Metals
   Transportation Equipment

3. Low-Research-Intensive Industries:
   Food, Beverages and Tobacco Products
   Rubber and Plastic Products
   Textile Industry
   Wood Industry
   Furniture and Fixtures
   Metal Fabricating
   Non-Metallic Minerals

4. Industries which perform no research and development:
   Leather Industries
   Knitting Mills
   Clothing Industries
   Printing and Publishing
   Miscellaneous Manufacturing Industries

Average annual rates of growth of employment, real output, productivity and prices between 1961 and 1974 were then cross-tabulated against the variously research-intensive industries and a generally superior economic performance was found at higher TI intensity levels, as is evident from Table 1.2.

TABLE 1.2

Average Annual Rates of Growth

1961-1974

Percent

	Employment	Real Output[1]	Productivity[2]	Prices[3]
Research-Intensive Industries	2.42	6.41	4.49	1.39
Medium-Research-Intensive Industries	2.75	6.60	3.95	1.64
Low-Research-Intensive Industries	1.61	5.19	3.47	3.13
No Research Industries	0.73	3.85	3.14	3.25
Total Manufacturing	1.87	5.79	3.82	2.37

1 1971 Dollars

2 Real Output Per Person

3 Value-added implicit price index

Source: MOSST Background Paper No. 4, Performance of Canadian Manufacturing Industries by Levels of Research Intensity, Ottawa, July 1978.

The implied causality is suspect both on grounds of TI definitional weakness and by reason of omitted variables, since subsequent more sophisticated investigations did not find any significant relationship between direct R&D and productivity. Using a similar classification, the Science Council of Canada, in its 1981 Hard Times, Hard Choices, analyzes -- with gloomy conclusions -- trade patterns in TI-intensive and non-intensive products. Canadian Science Indicators, 1983, an annual publication of Statistics Canada, devotes an entire chapter (ch. 9) to a similar analysis of trade patterns, with more finely defined industry commodities.

B) Product-based measures

There is widespread dissatisfaction with the rather clumsy approach that lumps arbitrarily all the R & D activities of a modern, typically well diversified firm, under one SIC industry umbrella. This dissatisfaction is strengthened by the fact that where a firm has several plants, census statistics assign the various outputs of these so-called establishments to relevant industrial commodity categories. It is therefore quite easy to come up with a fairly "clean" notion of SIC product category for the denominator of the TI definition of R & D/Output (or RD/Shipments or RD/Value Added).

The obvious solution is to query corporations in R & D surveys as to their R & D expenditure allocations by product line. The chief drawback is the existence of frequently centralized corporate research operations and consequently the arbitrary nature of R & D expense allocation to products or product lines, especially with regard to overhead. Nevertheless, the National Science Foundation (NSF) in the United States, in cooperation with the US Bureau of the Census, has been carrying out surveys of R & D expenditures according to the type of product or process which individual companies develop. Thus R & D expenditures carried out in a particular product category are combined into one number regardless of the industrial classification of the originating firms.

The US Department of Commerce has constructed a definition of TI based on this product-oriented measure, using the NSF R & D figure in the numerator and the census establishment figure for the denominator:

$$R \& D_{\text{product}}/\text{Shipments}$$

This is known as the DOC-2 definition, for Dept. of Commerce Mark 2. It is this definition which is used in analyzing international trade in products classified as technology-intensive or non-intensive.

Since product-related R & D expenditures are not gathered in Canada, MOSST -- in its background paper No. 5 -- uses the American DOC-2 definition to classify Canadian products by TI and to examine trade patterns.

Nevertheless, even the DOC-2 definition, or rather its NSF - product - R & D component, has its drawbacks. These have been discussed at length in Harry Postner's Economic Council of Canada discussion paper No. 244 issued in October 1983. Postner suggests so-called line-of-business (LOB) reporting by the larger multiproduct firms. LOB information has been exacted from large US firms by the Federal Trade Commission. The data bank generated by LOB reporting to the FTC has yielded a rich harvest of analytical studies into the R & D - productivity nexus. Essentially, LOB reporting taps existing internal management information systems. Since these are presumably profit-oriented, a reasonably sound allocation of total company R & D funds to the individual lines of business is possible -- and these lines, it is believed, can be made to approximate closely SIC product categories.

It is not necessary to go here into the further refinements of the generally-accepted basic definition of an industry's TI grounded in direct research except for one widely acknowledged conceptual weakness of all R & D outlay-based measures.

R & D Stocks

It is now generally accepted that expenditures on research and development are not current expenses but rather investments: they do not yield immediate returns and once their objective -- a new or improved product or process -- is attained, its revenue-generating or cost-decreasing action will decline over time. In other words, the research and development process takes time and may not have an effect on measured revenue or productivity until several years have elapsed. The example of new drugs, which take on the average ten years to bring to market from the moment of discovery, is perhaps the most extreme here. As new knowledge and know-how develop, the knowledge incorporated in past research results becomes obsolete and depreciates. If we capitalize the R & D outlays into assets or a "stock" of R & D, the growth in the net stock of R & D capital will not be equal to the level of current or recent expenditures invested in expanding it.

The first Canadian economists to go beyond current R & D outlays to the conceptually more satisfying notion of R & D stocks were Postner and Wesa, authors of the 1983 Economic Council's study Canadian Productivity Growth. In their study of productivity growth they employed such stocks, or rather the over-time change in them, as a determining variable.

This is how the stocks were calculated. For each of the two-digit manufacturing industries as well as other industries of the business sector, R & D intramural expenditures were deflated by the GNE implicit price index for machinery and equipment to 1971 constant dollars. Assuming a 10 percent depreciation rate and assuming that R & D expenditures in the first observed year, 1957, were only adequate to cover depreciation in that year, the R & D stock in 1957 was calculated to be the 1957 R & D expenditures times ten (Postner and Wesa, pp. 86-7). Then

$$RDSTOCK_{1958} = RDEXP_{1958} + (1 - 0.10)\ RDSTOCK_{1957}$$

and so on.

Table 1.3 shows, in the first column, the 1976 intramural stocks of R&D of the industry, converted back into 1976 current dollars. The second column lists the rank of the industry regarding the size of its R & D stock, going from largest to lowest. The third column has current dollars 1976 total intramural outlays (extramural outlays amounted to almost exactly 10 percent of intramural expenditures in 1976) and the fourth again the industry's rank going from highest to lowest R & D outlays.

TABLE 1.3

Intramural R & D Stocks and Total Intramural

Outlays in Canadian Industries in 1976

INDUSTRY	R & D STOCKS	RANK	R & D OUTLAYS	RANK
1. Total mines & wells	276.1	9	42	8
2. Food, beverage & tobacco	177.4	10	30	10
3. Rubber & plastic	53.8	13	7	13
4. Textiles	51.2	14	5	15
5. Wood based	295.5	8	35	9
6. Primary metals	438.2	4	67	5
7. Metal fabricating	78.1	12	11	11.5
8. Machinery	388.6	5	49	6
9. Transportation Eq.	741.5	2	88	2
10. Electrical Products	1307.1	1	172	1
11. Non metallic mineral	47.7	15	6	14
12. Petroleum Products	299.5	7	47	7
13. Chemicals	645.6	3	75	4
14. Miscellaneous Manufacturing	87.4	11	11	11.5
15. Transportation, other utilities & electrical power	303.1	6	77	3

Sources: R & D stock data supplied by H.H. Postner of the Economic Council;
R & D outlays from Standard Industrial R & D Tables 1963-1983, Science Statistics Centre SS 83-3.

Given the imprecision of the figures -- an assumed 10 percent depreciation rate; intramural outlays based on corporate reporting, but industry classification coming from the census establishment side; no extramural expense included -- it seemed best to rely on the non-parametric rank correlation coefficient test to see how well the relative positions of the industries concord with one another on these two measurements of R & D effort. The agreement, while very high ($r_{Spearman} = 0.97$) and statistically significant, is nevertheless not perfect. One would wish, naturally, to perform further tests with a longer series of data (say, going to 1981) before reaching a definite conclusion that for the ranking of industries as to "very-own R & D" intensity it matters or not whether stocks or outlays are employed.

CHAPTER 2

IMPORTS OF R&D: VISIBLE AND INVISIBLE

General Remarks

A Science Council of Canada publication (Hard Times, Hard Choices November 1981, p. 58) states that "foreign control of high-technology industries stood at 70 percent in 1978 and, as has been well documented, foreign-controlled firms in nearly all manufacturing sectors do a lot less R&D relative to sales than do domestically controlled firms."[1] The convincing documentation that foreign-controlled firms do less R&D relative to sales in Canada is presented in the Economic Council's The Bottom Line (1983, pp. 40-42).

The seeming paradox of foreign subsidiaries being heavily represented in R&D-intensive industries -- intensive, at least, on the "direct" or "very own" definition -- and yet being less R&D intensive than their Canadian counterparts is resolved when it is recalled that such subsidiaries have less need to undertake research locally since they can rely on acess to R&D results generated by their affiliates abroad. Statistically this resolution can be confirmed if either or both of the following conditions hold:

1. R&D - or technology-related payments abroad of foreign subsidiaries are relatively higher than those of Canadian-owned firms and most of these payments go to affiliated companies
2. foreign subsidiaries benefit from invisible, that is free-of-charge, imports of R&D results from their parents or affiliates abroad.

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[1] Among higher-technology industries the Science Council includes scientific equipment, chemicals, electrical, machinery, and aircraft and parts, somewhat along the lines of the MOSST classification mentioned in Chapter 1.

This argumentation has by now gained wide acceptance and it is somewhat surprising that it has not led to a general revision of TI calculations. (See, in particular, MOSST background papers No. 3, Importation of Invisible R&D, 1974-76, July 1978, No. 9, R&D in Canadian and Foreign-Controlled Manufacturing Firms, 1979, and K. Palda and B. Pazderka, International Comparison of Canada's R&D Expenditures, Economic Council of Canada, 1982).

Visible Imports

Condition No. 1 is documented in Table 2.1, based on MOSST paper No. 9. The table shows foreign-and Canadian-controlled shares of sales and R&D outlays before and after adjustment for R&D plus technology-related payments to non-residents: after adjustment the shares "even out."

TABLE 2.1

Shares of Sales, R&D Expenditures, and R&D Expenditures Augmented by Technology-Related Payments to Non-Residents, 1975

Industry	Canadian-Controlled			Foreign-Controlled		
	% Sales	% RD	% RD+	% Sales	% RD	% RD+
Pulp and Paper	56.4	67.2	52.7	43.6	32.8	47.3
Primary Metals	82.9	86.0	78.9	17.1	14.0	21.1
Electrical Products	34.4	59.2	53.2	65.6	40.8	46.8
Machinery	32.5	31.4	25.0	67.5	68.6	75.0
Chemicals	17.1	31.7	19.7	82.9	68.3	80.3

Source: Tables 5 and 10, MOSST Background Paper No. 9.

Total payments in support of R&D to non-residents amounted to $74 million in 1975, of which about 80% went to "related firms"; payments in support of technology (products, industrial design, royalties, scientific and research sciences) totalled $119 million and it is likely that the bulk of these payments went to affiliates as well.[2]

Statistics Canada publications give information on technological payments by industry, but offer only aggregate, all-Canada figures on R&D payments. Table 2.1 is therefore based on special tabulations which MOSST had requested from Statistics Canada. It is for this reason, the absence of special tabulations, that more recent figures cannot be shown here. Similarly, special tabulations would have been required to get a broad picture of invisible imports, the second condition mentioned above. An effort was made, nevertheless, at a partial up-date of a study by MOSST which was the first to indicate to what extent "gratis" - at least in the accounting sense - transfers of technology flow into Canada (MOSST Background Paper No. 3).

Invisible Imports

In order to verify if the second condition holds, namely that foreign subsidiaries benefit from invisibile, free-of-charge imports, stronger assumptions must be made than with respect to R&D and technological payments.

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[2] This information and judgement is based on the Annual Review of Science Statistics, 1978, p. 35; Standard Industrial R&D Tables 1963-1983, SS83-3; and D. DeMelto et al., Discussion Paper No. 176, Economic Council, October 1980.

First, the assumption is made that parent/affiliate and subsidiary produce similar products using similar processes, and that R&D performed by the parent is applicable to, and tends to flow to the Canadian subsidiary. Second, an assumption is also made that the amount by which the subsidiary benefits from the whole group's R&D is proportional to its share of the whole group's sales. This is a very conservative assumption since the fruits of R&D within a multinational enterprise are most likely to be of the nature of public goods: any member firm of the multinational group is allowed access to it, no matter what its "taxes", i.e. transfer payments to the group.

This leads to the following formula for the invisible imports of R&D by a foreign subsidiary in Canada:

RD(Invisible) = RD (Notional) - RD(Canadian) - RD(Payments) .

where

RD(Notional) = RD(Group)/Sales(Group) times Sales (Subsidiary)

RD(Canadian) = the subsidiary's intra-and extramural R&D

RD(Payments) = the subsidiary's payments to non-residents for technology acquired

It is to be noted that the formula is conservative not only on account of the public good aspect, but because technology-related payments (the only ones available at industry level) exceed R&D payments by about one third. Also, the formula does not preclude a negative figure: it is possible that a foreign subsidiary exports invisibly.

Using the approach determined by the formula, MOSST No. 3 background paper estimated 1974, 1975 and 1976 invisible R&D imported to Canada for the sectors mining, petroleum, food, beverages, tobacco, machinery, transportation equipment, metal fabricating, paper and allied, electrical products, rubber and plastics, chemicals, utilities and transportation. For the year 1976 these invisible imports amounted to \$655 million, two-and-a half times higher than Canadian - located intra-and extramural R&D in these sectors. THUS, INVISIBLE R&D IMPORTS ARE LIKELY TO REPRESENT THE MOST SUBSTANTIAL COMPONENT OF ALL THE R&D OUTLAYS THAT SHOULD BE COUNTED IN TO REACH AN ADEQUATE APPRAISAL OF AN INDUSTRY'S TECHNOLOGICAL INTENSITY, WHETHER ONE OR THE OTHER DEFINITION IS RESORTED TO.

Because of the importance of this component, a detailed example of the calculation of 1981 invisible R&D imports is given here -- for the three-digit SIC industry 374, pharmaceuticals and medicines.

Invisible R&D Imports by the Canadian Pharmaceutical Industry

The example shows a step-by-step procedure which is determined by the formula given on the preceding page.

Notional R&D of foreign pharmaceutical subsidiaries in Canada is calculated by first compiling data on as large a sample of such firms as can be obtained (Table 2.2) and then "projecting" these data to a total population of foreign drug subsidiaries.

TABLE 2.2

Global Sales and R&D and Canadian Sales
and Notional R&D of 14 American Pharmaceutical
Companies in 1981
(in $ millions)

Firm	R&D Global	Sales Global	Sales Canadian	R&D Notional Canadian
Abbott Prod.	108.9	2313	46.76	2.202
Am. Home Prod.	111.2	4083	104.2	2.838
Baxter	58.6	1485	34.24*	1.351
Bristol-Myers	142.0	3492	35.90	1.460
Johnson & Johnson	260.1	5375	54.41	2.633
Lilly	238.0	2762	24.41	2.103
Merck	266.4	2922	84.29	7.685
Pfizer	174.5	3236	23.42	1.263
Shering Plough	106.3	1809	27.17	1.597
Searle	80.3	933	21.02	1.809
SKF (Or SKB)	215.7	2607	67.39	5.576
Sterling	66.8	1791	23.95	0.893
Syntex	60.5	696	32.90	2.860
Warner Lambert	106.6	3376	43.18	1.363
Total			623.24	35.633

* Interpolated

Sources: Global R&D and sales, Business Week, June 20, 1983; Canadian sales via Consumer and Corporate Affairs, Compulsory Licensing of Pharmaceuticals, 1983, p. 8.

Table 2.2 shows the group (world-wide) sales and R&D of 14 multi-nationals, and the sales and R&D expenditures of their Canadian subsidiaries. The group data were obtained from the "R&D scoreboard" published by Business Week on June 20, 1983 (as every year around that time). Though not overtly indicated, it would appear that both sales and R&D figures are given for the companies' world-wide operations. The sales of the Canadian subsidiaries were calculated from Table 1 of the Consumer and Corporate Affairs Canada report on Compulsory Licensing of Pharmaceuticals, published in 1983. This table indicates the Canadian subsidiaries´ sales as a percent of the firms´ global sales.

The notional R&D of these 14 subsidiaries is estimated in Table 2.2 at $35.6 million in 1981. To estimate the notional R&D of all foreign drug subsidiaries a "projection to universe" must be made:

a) calculate a multiplier

K = Sales of all foreign subsidiaries/sales of sample

= (0.85)($1,327 million)/$623.2 million = 1.82
(Market share of foreign drug subsidiaries in the seventites from Palda and Pazderka, op.cit., p. 52; 1981 total drug sales from Consumer and Corporate Affairs, op.cit., p. 18);

b) assuming that R&D in universe is proportional to sales in the same way as in the sample,

total notional R&D = 1.82 times $35.6 = $64.8 million.

Next, the Canadian-performed R&D of all foreign drug subsidiaries must be estimated. Very likely a fairly accurate figure could be obtained from a special Statscan tabulation. In its absence the estimate of 1981 Canadian R&D is derived very simply. 1981 R&D intramural outlays in the pharmaceutical industry were $51 million. Using the 85 percent sales share held by foreign subsidiaries, we calculate (0.85 times 51) that about about $43.4 million was performed by foreign subsidiaries.

Finally, net payments to non-residents for technology acquired (more than just R&D results) by the drug industry amounted to $7 million in 1981 (payments of $17 million, receipts of $10 million). Perhaps 85 percent, or $5.95 million, are the foreign subsidiaries´ net remittances.

Using the overall formula, we can now estimate the total invisible R&D imports by foreign subsidiaries in the Canadian pharmaceutical industry to be

= \$64.8 - \$43.4 - \$5.9 = \$15.5 million in 1981.

It is well known that the Canadian pharmaceutical industry, despite its high though now declining foreign ownership, is a heavy spender of "very own" R&D funds. Nevertheless, its invisible R&D imports amount to a quite considerable 30 percent of own-performed outlays. At the other end of the spectrum is the transportation equipment industry, SIC 32, which is largely foreign-owned and in which only the aircraft and parts industry, SIC 321, is domestically research-intensive. Estimated 1981 R&D invisible imports are \$669 million.[3] Somewhere in the middle lies the pulp and paper industry which is less than one-third foreign-owned and has a reasonable record of domestic research performance. Its invisible 1981 R&D imports are calculated to be \$21 million. Thus for the 32 SIC group imported R&D represented about the double (\$669 million) of domestically performed R&D (\$296 million); for pulp and paper, SIC 271, it represented only about 26 percent.

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[3]Calculations of imported invisible R&D for the transportation equipment and pulp and paper industries are set out in the appendix to chapter 2.

APPENDIX TO CHAPTER 2

Calculations of Invisible R&D Imports in 1981 for Pulp and Paper and Transport Equipment Industries

Pulp and Paper

Usable data were obtained for Crown Zellerbach, Kimberly-Clark and Scott Paper: total Canadian sales of $1373 million in 1981 and notional R&D of $11.7 million. The multiplier to universe was calculated as

$$K = 5072/1373 = 3.7$$

where $5072 million comes from CALURA 1981, p. 155. Thus notional R&D of all foreign paper subsidiaries is (11.7 times 3.7) or $43.3 million. Actual domestic R&D of all the subsidiaries is estimated to be proportional to the foreign-held share of sales, estimated for CALURA to be 27.9 percent: thus 27.9 percent of $80 million spent on R&D by this industry in 1981 is $22.3 million. No figure is available for this industry for tehnology-related payments (or receipts) abroad. Thus

Invisible R&D imports =	Notional R&D of all foreign owned subsidiaries	less	actual R&D of all foreign-owned subs	less	payments abroad

$21M = $43.3M - $22.3M - 0.

Transport Equipment

Usable data were obtained for United Technologies (Pratt and Whitney in Canada), Chrysler, Ford and General Motors: total Canadian sales of $20,880M in 1981 and notional R&D of $797M. The multiplier to universe was calculated as

K = 24,484/20,880 - 1.17

where $24,483 million comes from CALURA 1981, p. 155. Thus notional R&D of all foreign subsidiaries is (797 times 1.17) or $932.5 million. Actual domestic R&D of all the subsidiaries, on the assumption that it is proportional to the foreign-held share of sales -- estimated by CALURA to be 85 percent -- is ($296M times 0.85) or $252 million. Payments for technology abroad are estimated as 85 percent of $8M (aircraft and parts) and of $5M (other transportation equipment - payments between Canadian companies and foreign affiliates for R&D only - see Table 28, SS83-3), or $11 million. And so

Invisible R&D imports = $932.5M - $252M - $11M = $669.5 million.

Finally, it should be mentioned that the assumption that the share of R&D domestically performed by foreign subsidiaries is equivalent to their share of Canadian-originated output is unrealistically high. This, however, leads to an underestimate of invisible imports and makes our conclusions more conservative than they deserve to be.

CHAPTER 3

GOVERNMENT INTRAMURAL R&D ASSIGNABLE TO INDUSTRY

General Observations

The private sector receives public support for its technological activities under various guises: direct subsidy, contract, technological information, tax incentives, and so on. The monetary value of some of these supports is "captured" on the receiving end by Statistics Canada in its annual surveys of research-performing firms. For instance, direct subsidies would be revealed, such as the (former) Enterprise Development grants, or the contributory portion of the Industrial Research Assistance Program of the National Research Council. Government contracts would also be reported.[1] Thus such government outlays are already included in the R&D expenditures of individual industries as reported by Statistics Canada and are an integral part of the direct or very-own research intensity count.

Other taxpayer-supported outlays which are expended directly on behalf of the various industries through various governmental agencies are, however, identifiable only with some difficulty. The largest of these government efforts on behalf of industry is undoubtedly a portion

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[1]Since the surveys reach only a (large) sample of the beneficiary firms and the questionnaires may not be carefully filled out, the Science Statistics Centre of Statscan is currently endeavouring to match the grantors' reports with the receptors' figures.

of the substantial intramural research carried on by the various federal and provincial ministries. The second largest outlay is probably backing the dissemination of technical information from government laboratories to industry, such as via NRC's IRAP-F program.

The scope of this study precludes giving a broad statistical picture of governmental intramural research assignable to various SIC industries. Rather, some examples will be offered to show that a dent can be made into the current anonymity of most public intramural research outlays. As regards the dissemination of technical information it will be admitted that no assignable outlays can be found with present reporting systems. Nevertheless, the goal is to demonstrate that in a country in which 22 percent of all research expenditures are "performed" by the federal government,[2] some substantial sums financing this performance must perforce redound to the benefit of individual industrial sectors. The most obvious, acknowledged, but generally forgotten instance is the case of Agriculture Canada which is budgeted to spend $250 million on in-house R&D in fiscal 1984-5.

Before outlining the posibilities of assigning intramural federal government research (no comprehensive figures on provincial R&D are available) to specific industries, it is instructive to consider some of

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[2]Provincial governments are not included, universities whose research is funded by public funds and who - as shown in the next chapter - undertake research work of direct interest to industry account for another 19 percent of research performance. See Science Statistics Centre publication SS 1983-5, Table 11.

the pertinent federal research statistics themselves. Table 3.1 shows federal expenditures on research and development in the natural sciences by performer for the fiscal year 1984-85. About 55 percent of those outlays, or $1.3 billion, went to intramural research of government departments or agencies. Table 3.2 lists, for the same fiscal year, intramural expenditures and total expenditures of the seven highest-spending departments or agencies. These account for 62 percent of federal intramural R&D expenditures. The difference between total and intramural expenditure which is money spent by the departments elsewhere than within its walls or under its proper management is largest for the National Research Council and the Dept. of National Defence, both of which support massively research in the private sector in a direct way. Finally, Figure 3 gives a graphic impression of the size of the federal research effort by showing the distribution of scientific establishments and personnel across Canada in 1982-83.

TABLE 3.1

Federal Expenditures on R&D in Natural Sciences
By Performer, 1984-85
($ millions)

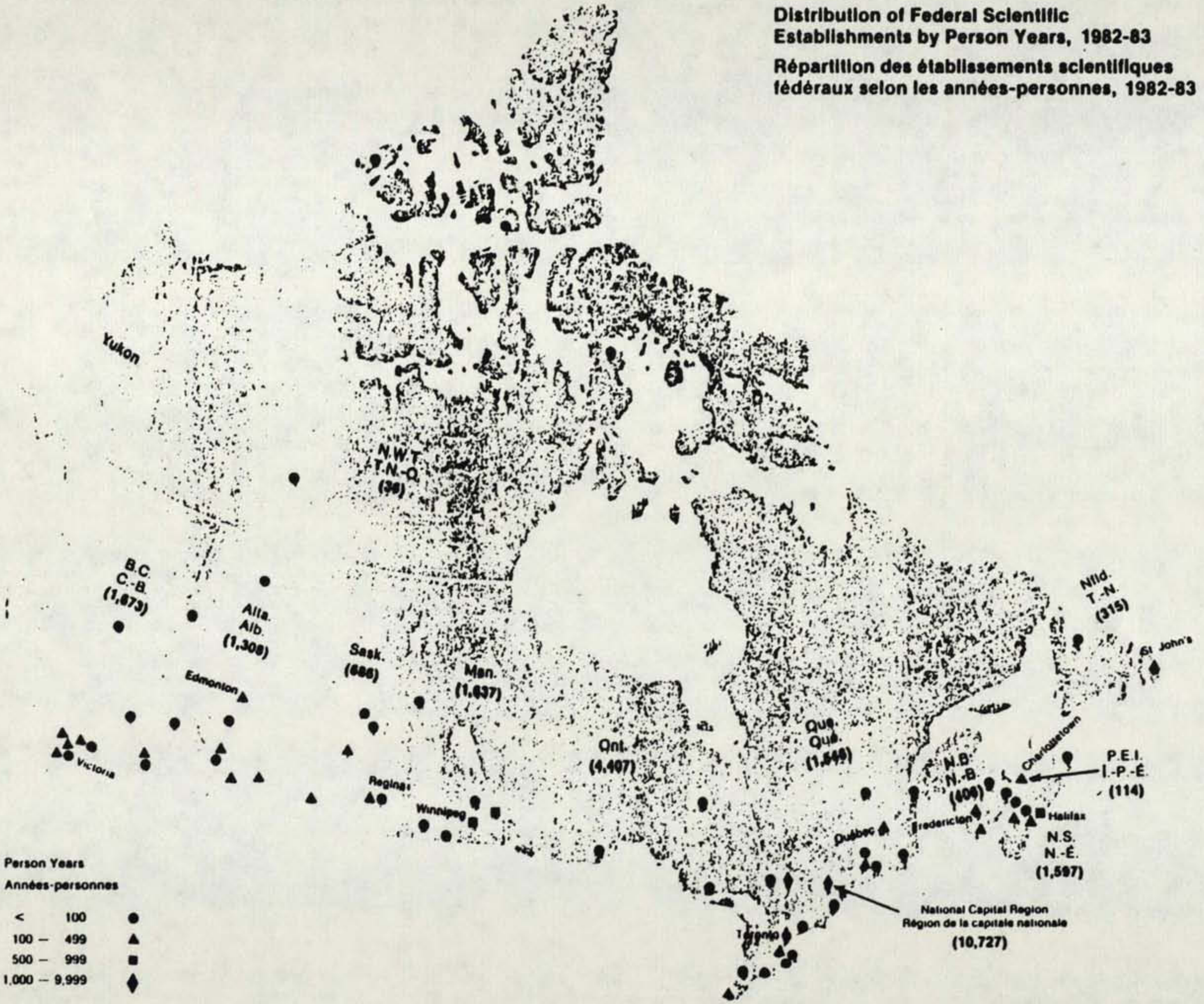
Performer	$	%
Intramural	$1,343.8	55.4
Industry	518.7	21.4
Universities	453.6	18.7
Non-profit Institutions	10.2	0.4
Provincial and Municipal	7.2	0.3
Foreign	71.5	2.9
Other Canadian	20.3	0.8

Source: Science and Technology Division of Statistics Canada, Federal Science Expenditures and Personnel 1984-85, Table 32

FIGURE 2

Distribution of Federal Scientific Establishments by Person Years, 1982-83

Répartition des établissements scientifiques fédéraux selon les années-personnes, 1982-83



Source: Statistics Canada, SS 84-1

Assignable Intramural R&D

We now turn to the seven heaviest intramural spenders as listed in Table 3.2 to examine the feasibility of classifying some of their intramural R&D as being of direct, "targetted" benefit to SIC industries. The departments and agencies are discussed in increasing order of the difficulty with which assignments can be made.

First, however, two general remarks are in order. Most governmental departments or agencies do not carry out scientific research or development solely to serve the needs of the private sector, but also to throw light on questions of relevance to themselves -- presumably in the national interest. One might, of course, argue that national interest stands for the individual economic interests of Canadians. The reply is that the national interest may be represented as the interest of several economic sectors and that "national-interest" research cannot be plausibly "charged" to any of these sectors. The classical example is acid rain pollution, a phenomenon of many natural resource and industrial participants.

Second, some of the research carried out federally tends to be closer to the fundamental rather than to the applied-developmental kind. This means that it is quite premature to demand that its benefits be stated to flow to well-defined industries; it may even be that such industries are not in existence yet. The National Research Council, for instance, prides itself on being so forward-looking in many of its activities that an SIC-classification simply cannot catch up to them. In the NRC

TABLE 3.2

Federal Intramural and Total Expenditures on R&D in Natural Sciences ,

Selected Departments or Agencies, 1984-85

($ thousands)

	Intramural	Total
National Research Council	$292.5	$464.9
Agriculture	264.1	280.8
Energy, Mines and Resources	168.6	265.3
Fisheries and Oceans	137.2	147.4
Atomic Energy of Canada Ltd.	122.6	130.2
Environment	115.3	135.0
National Defence	109.9	199.6

Source: Science and Technology Division of Statistics Canada, Federal Science Expenditures and Personnel 1984-85, Table 34 discussion paper No. 23 of December 1982, J.E. Fisher speaks of the example of robotics, a word which does not appear in the 1970 SIC manual. Furthermore -- and this harks back to our discussion in Chapter 1 -- robotics "production may be classified along with washing machines or computers or electric motors" because of the way output data are collected.

1. Agriculture

Of Agriculture Canada's $280 million projected as 1984-85 expenditures on research and development, the bulk - $164 million - is budgeted to "production development", whose aim is to "assist in increasing the efficiency and improving the quality of primary food and agricultural production" (Agriculture Canada's 1984-85 Budget Estimates, V.3, p. 23). Most of those funds are spent intramurally, as is evident from Table 3.2.

Table 3.3 lists 4 of the 6 lines of research undertaken under the umbrella mission name of "production development." It is perfectly clear from this table that, with the possible exception of the $1 million item "farm input supply research", all of the $144 million is spent in support of SIC major group 01, agricultural industries. It is not, however, possible to assign the research outlays more finely to 3-digit industries. An example would be the attempt to split animal production development research between 011 (livestock farms) and 012 (other animal specialty farms - bees, horses, etc): the figure of $36.6 million is not disaggregated further in official documents and the writer's endeavours to obtain directly such figures did not meet with success.

This, however, seems hardly to matter since it is common knowledge that the industry, fragmented into thousands of small-scale units, does not undertake any research on its own, but is entirely dependent on federal and provincial research activities, as well as on the activities of its commercial suppliers, such as fertilizer and farm implement manufacturers. What would be interesting is to calculate agriculture's total research intensity, which is wholly "received" from the outside of this SIC 2-digit private sector and to see whether it falls short of other 2-digit major groups, such as some in manufacturing. Such a calculation is beyond the scope of our task which is limited to the assembly of pertinent examples and illustrations of each TI component.

TABLE 3.3

Research on Production Development
1984-85 Budget Estimates
($000)

Activity	Expenditures	Overall Output	Example of Initiatives
Animal Production Development	$36.6	Improvement in efficiency of production and quality of animals	Development of new strains of honey bees
Crop Production Development	67.3	Improvement in efficiency of production and quality of crops	Improvements in greenhouse tomato and cucumber production
Production Support	39.3	Ensure availability and development of basic support services	Increase nitrogen-fixing capabilities in plants
Farm Input Supply	1.0	Ensure availability and development of basic support services to the food and agriculture production system	Development of machinery for a variety of crops, such as herbs, rhubarb

Source: Agriculture Canada, <u>1984-85 Budget Estimates</u>, V.3, p. 28.

There is, nevertheless, one strand of research undertaken in Agriculture Canada which seems to benefit one industrial grouping that engages in research on its own as well. In this sense we deal with what can be considered the more typical situation: government-performed R&D augments an industry's technological activities. Called processing research, its "overall output" is the "promotion of increased technological innovation and efficiency in the (food) processing sector;" in 1984-85 the budget is set at $15.6 million.

One example of the research initiatives is the investigation of the influence slaughtering and processing techniques have on meat quality. This, presumably, is to help the 3-digit industry "Meat and Poultry Products" which bears identification number 101. Another example is research to make new yeasts available to the wine industry and to develop a computer program for fermentation control. The wine industry bears the SIC number 114. As in the previous instance, there is however no disaggregation of the $15.6 total research figure possible and all that can be said is that this money is spent on behalf of industry groups 10 (food), 11 (beverages) and possibly 12 (tobacco products). A minor effort at reading internal documents would undoubtedly lead the government department to a feasible assignment classification since we deal here with the development end of the R&D spectrum.

Statements, such as the following one taken from the proceedings of the food R&D seminar, organized by Agriculture Canada on April 19-20, 1983 (p. 18), only leave the external investigator "sur sa faim":

A few examples of productive research of direct relevance

to the industry are:
Canola - margarine, cooking oils
High nitrogen oats - breakfast cereals
Clingstone peaches - canning
Shepody potatoes - french fries
Hogs - bacon
Lean cattle - low fat meats etc.

2. Fisheries and Oceans

Fisheries research as well as hydrography and oceanography activities account for the total outlays of $267 million on R&D and RSA (related scientific activities, that is, activities which complement and extend R&D by contributing to the generation, dissemination and application of scientific and technological knowledge) in both natural and human sciences. It is well-nigh impossible, on the basis of published datas, to make a precise assignment of the intramural R&D in natural sciences only, listed as $137 million in Table 3.2, between fisheries research and the other research. The surveying and mapping of marine waters (hydrography) and the vast field of oceanography is indicated in the budget estimates as absorbing $128 million , but most of it is probably RSA. These two activities are so diffuse in character (benefits to navigation, oil exploration, meteorology, basic marine ecology) and so little financial detail is available about them that no assignment to SIC industries is attempted.

Fisheries research, on the other hand, is clearly focused on fresh and salt water fish and other aquatic life -- by interpretation of offical documents and by confirmation from the department itself. And so the somewhat trivial conclusion that somewhere between $100 and $120 million is being spent intramurally by Fisheries and Oceans on research benefitting industrial groups 031 and 032, fishing industries and services incidental to fishing. The fish products industry, SIC 102 is, according to direct information provided by the department, not an intended "target" of Oceans and Fisheries research. (Incidentally, no R&D for the benefit of fish processing could be discovered in Agriculture Canada either; possibly Maritime and B.C. provincial funds support research in that area).

3. Energy, Mines and Resources

EMR is the third-highest intramural R&D spender among the federal establishments with $168.6 million budgeted for 1984-85. Almost all of this, namely $165.6 million, is accounted for by the Minerals and Earth Sciences sectors. Within that sector minerals technology, energy technology and remote sensing appear as the three predominant recipients of R&D funds. Applying 1983-84 percentages obtained directly from the department (84-85 percentages were not available as of the time of writing) to 1984-85 budget forecasts, the intramural R&D funds spent on the three activities are estimated to be $19.9 million, $32.0 million and $24.9 million, respectively. Table 3.4, based on the 1984-85 budgetary estimates, makes an attempt at the assignment of specific research projects listed in the estimates to specific SIC industries on the assumption that these projects were carried out intramurally. In future work such an assumption can, of course, be verified directly with the deparment. In the present instance the intra-extramural allocation could only be done with respect to activity areas rather than individual projects.

TABLE 3.4

Identified, Mostly Intramural R&D Carried Out by EMR
Assignable to SIC Industries, Fiscal Year 1984-85

Activity Area	Beneficiary Industry	Amount ($ million)	Specific Example
MINERALS TECHNOLOGY			
	Metal Mines 061	$8.5	Improved recovery of metal values from complex sulphide ores
	Primary Metal 29	3.2	Demonstration mobile foundry
Total area	$29.3		
Est. intramural[1]	19.9		
ENERGY TECHNOLOGY			
	Petroleum 07	15.5	Paper: Demonstrating efficient, environmentaly acceptable combustion systems for steam generation from waste wood
	Coal Mines 063	21.1	
	Uranium Mines 0616	1.5	
	Paper, Allied 27	1.5	
Total area	$47.7		
Est. intramural[1]	32.0		
REMOTE SENSING			
	Agriculture 01	2.6	Extending potato acreage estimation for P.E.I.
Total area	$26.2		
Est. intramural[1]	24.9		

[1] See text for estimate derivation

Source: Energy, Mines and Resources Canada, 1984-85 Budget Estimates, V.4.

4. Environment

Of the intramural research outlays of \$115.3 million budgeted for 1984-85 the Dept. of Environment committed the largest share -- \$50.5 million -- to its Canadian Forestry Service. This activity area is more susceptible to "assignment" than the others: the atmospheric environment service which includes meteorology (\$33.2 million intramural), the environmental conservation service (\$26.0 million) and the environmental protection service (\$4.5).

Nevertheless, the largest portion of the Canadian Forestry Services' internal R&D appears to be assignable only in an obvious and almost trivial sense, that is to major SIC groups 04 (logging), 05 (forestry services), 25 (wood) and 27 (paper and allied), without a rigorous discrimination even among these. The CFS runs six regional centres and two national research institutes. These engage in investigations into forest environment, production, protection and utilization. A careful examination of the annual reports of each of these eight research centres-institutes disclosed only one possible other industrial group which might benefit from CSF R&D. These are chemicals (SIC 37) or even pharmaceuticals (374). The activities of the Forest Pest Management Institute in Sault Ste. Marie (\$36 million in 1982-83) were clearly aimed at the development of insecticides, herbicides or means of biological control (Environment Canada, Canadian Forestry Service, Program Review 1982-83, Forest Pest Management Institute).

5 Atomic Energy of Canada Limited (AECL)

Under the ministerial wing of EMR, AECL is a crown corporation with a partial for-profit orientation and substantial commercial revenues. Its annual report for the fiscal year ended March 31, 1984 states that $211 million was spent on R&D, of which $184 million was financed by parliamentary appropriations. This does not tally with the $123 million listed in the 1984-85 federal science expenditures report of Statistics Canada for that year for both intra - and extramural R&D outlays in the natural sciences (Table 34).

We shall, for consistency's sake, take the federal statistics as our reference point and ask to what extent the federally funded $122.6 million budgeted for 1984-85 intramural R&D can be allocated to SIC industries. AECL's expenditures appear to be assignable only to the service industry Electrical Power Sector, SIC 572 or to the manufacturing industry, Electrical Industrial Equipment Sector, SIC 337.[1] This is despite the fact that AECL indicates that it executes technological transfer to private industry, and charges for this service (although not fully recovering the costs to them). A transfer of technology from AECL to another SIC sector, such as scientific instruments SIC 391, provided it takes place at less than cost, is really and unambiguously R&D done for the benefit of this sector.

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[1] Once again, there are inconsistencies between Statistics Canada and AECL. In FY 1981-82 AECL, according to its annual report, spent $167 million on R&D but Statscan (SS 83-3) lists only $178 million for the two categories combined, with big R&D spenders Hydro Quebec and Ontario Hydro present in SIC 572. A direct inquiry to the Science and Technology Statistics Division of Statistics Canada met with no success, given the confidential status of reports on R&D by commercially-oriented firms or crown corporations.

But to put a dollar figure on this transfer is of course another matter. The best that can be done is to quote a paragraph from a letter received by the writer from AECL's Research Company (dated August 9, 1984):

> Nuclear fuel. AECL decided very early in the nuclear program that production of the nuclear fuel for the CANDU reactors would be done by industry, not by AECL. We therefore transferred our fabrication R&D knowledge to Canadian General Electric and Westinghouse, to set them up as fuel suppliers. We purposely set up two companies, to provide competitive bids and to avoid the definite problems associated with a sole source.
>
> There are no published figures on the government funded R&D associated with this development program; it is possible to estimate the total as several millions of dollars.

Since 1979 AECL has developed a more articulate policy of transfer. As a recent article states, Chalk River (the main laboratory centre of AECL) has been gearing up to make its resources, formerly heavily devoted to the nuclear industry, available to non-nuclear industries as well (A. Scott, "Chalk River - A Technology Transfer Centre," Engineering Digest, Nov/Dec 1982). To the extent that not all costs are recovered this policy would directly support the non-nuclear sectors.

6. The National Research Council

NRC is the federal government's largest and most diversified research organization and the single largest spender of R&D funds: in 1984-85 $465 million according to Statscan and $489 according to the "blue book" budget estimates. Almost one-third of the total is spent extramurally, in the form of contracts, grants, university support, international intergovernmental programs and so on. If we follow the "blue book" budget estimates, we note that of the total $489 million, $218 million is earmarked as in "direct support of industrial innovation and development," as opposed to such other missions as "national competence in natural sciences and engineering."

"Research and development <u>conducted</u> by NRC laboratories in support of industry provides the basis for new industrial products and processes," (Budget Estimates 1984-85, V.2, p.32), is a statement which gives encouragement to the search for assignability. $115 million was allotted for this type of <u>intramural</u> R&D, but only two laboratories can be clearly identified as having a specific 2-digit industrial sector orientation: Building Research ($2.9 million in 1984-85) and the National Aeronautical Establishment ($9.9 million).

Building research is of clear benefit to two industrial groups, one being SIC 35, non-metallic mineral products (cement, glass, etc), the other the construction industry itself, SIC 40 to 42. Another item, classified under NRC mission "research on problems of economic and social significance," claims $8.8 for the Division of Building Research (example: behaviour of Canadian contruction materials under severe climatic conditions) and should undoubtedly also be of support to these two industries, provided it takes place within NRC's walls. SIC 321 group Aircraft and Parts is the obvious beneficiary of the work undertaken by the aeronautical labs.

What of the important technological transfer activity of NRC? Some of its supporting outlays under the acronyms of IRAP and PILP are already "captured" by the reporting of companies surveyed by Statscan. However, many of these firms are, by the very nature of the transfer assistance programs, too small and escape the reporting net.

IRAP, the industrial research assitance program, has also a field advisory service component (IRAP-C) and a technical information service (IRAP-F). Quite apart from this the 1982-83 annual NRC report, in its Table 5, lists an outlay of $20.6 million for its scientific and technical information program that covers such diverse activities as the operation of on-line search systems at the request of external enquirers. The problem, again, from our point of view, is the accounting allocation of these dissemination activities to specific industrial sectors. The farthest one can go under present circumstances is to obtain a computer list of "contacts" between NRC labs and industry. Such a list exists; in calendar year 1983, for instance, NRC had "informal" interactions -- no contractual or formally documented agreement - with 729 firms, identified by name of contact person and the corporation. To decide which SIC sector the firm is in and how much outlay an "interaction" caused the NRC are, however, well-nigh impossible tasks.

As was already mentioned the National Research Council defends plausibly its position that the majority of its outlays back research that is sufficiently frontier-like that benefits to specific industrial sectors cannot be forecast. In this sense, then, the attempt at assignability is doomed even more than in the case of AECL which can be said to exert its activities mainly in the electrical products and electrical generating sectors -- a finding of little import to our interest in downstream effects. The "non-assignability stance," if such an expression may be coined, can expose government laboratories to such criticism as recently proffered by the Wright Commission (Task Force on Federal Policies...., op. cit.):

> The research they (federal laboratories) produce on industry's behalf is seldom used by the industry in question -- which is hardly surprising, since industry is seldom asked whether or not they need it (p.27);

and

> Because their (i.e., of such federal labs as are directly supporting governmental tasks of national interest) main client is the federal government, these laboratories often have even greater difficulty in defining their missions than do labs whose main function is to support industry goals. Inertia, irrelevance, overlapping departmental mandates and jurisdictions are clear and present dangers. These intra-government relationships often lack the results-oriented discipline which characterizes most market transactions (p. 28).

7. Dept. of National Defence

As can be observed in Table 3.2, National Defence carries out $110 million worth of R&D in its defence research establishments and contracts out another $90 million, of which 90 percent goes to industry. Defence-oriented manufacturers are also beneficiaries of the DIPP (defence industry productivity program) funds, designed to enhance the technological competence of its member firms. In 1983-84 DIPP's budget was $148 million.

A careful search of published documentation and direct contact with DND failed to reveal any outlays on intramural R&D which could be attributed to specific industries. It is possible that the items listed under the heading of "Defence Services Program - Major Capital Projects - Development" in the blue budget estimates book of 1984-85 refer to R&D. Most of these are of what could be termed the "communication and other electronic equipment" kind, bearing SIC code 335, such as a towed array power system ($6 million of the total 1984-85 "development" budget of $29 million).

CHAPTER 4

UNIVERSITY RESEARCH FOR THE BENEFIT OF INDUSTRY

Industry or individual firms commission research from universities though the amount is not very substantial: about $4 milions´ worth in 1982, if we take the funds coming from the business enterprise sector to the higher education sector to represent extramural outlays by industry (see SS 83-5, R&D Expenditures in Canada, 1963-83, p. 31). A much more important source of funding of university research whose fruits could be directly assignable as of benefit to specific SIC industries are the federal and provincial governments and, in particular, the National Sciences and Engineering Research Council, NSERC, which is a granting agency of the federal government.[1] NSERC´s annual funding of university research is now at the quarter-billion mark and thus it is tempting to seek in its reports indications of grants that support research directly applicable or assignable to industry.

To see if this could be done a direct enquiry to NSERC was made, but little actual information obtained. It was indicated that the only possible source of pertinent data might be the actual lists of grants which describe the name and university affiliation of the researcher(s), the title of the project, and the amount of the grant. Therefore an

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[1] The National Research Council spent about $25 million on university support in 1982-83, as indicated in its annual report.

information bulletin (Information, NSERC: Ottawa, December 2, 1983) was analyzed which carried news of 487 grants in the fields of biotechnology, communications and computers, energy, environmental toxicology, food and agriculture, oceans, and "others". The total funding for these grants amounted to $28.1 million. Attention was focused on the 134 projects in the energy field, of which 64, worth a total of $3.3 million (out of $7.8 million), could be classified rather easily as falling under the heading of a specific 2 - or 3 digit SIC industry. This can be seen by examining the descriptions of some research projects listed in Table 4.1.

TABLE 4.1
(page 1)

Classification by 2 Digit SIC Industries of NSERC Strategic Grants to University Researchers, December 1983, Selected Figures

Total Grants (covers biotechnology, communications & computers, energy, environ., toxicology, food & agr., oceans, open)	No of Grants: 497	$28.1 million
Energy[1]	No of Grants: 134	$7.8 million
		($)
Mineral fuels	10	715 303
Paper	4	124 182
Primary metals	3	178 560
Trans. equipment	3	131 618
Electrical products	13	672 931
Petroleum & coal	13	577 456
Chemicals	2	66 226
Construction	7	475 053
Electric power & gas	9	371 758
		3 313 087
Not classifiable	70	4.487 M

[1] Examples of classification are given for each SIC industry on p. 2 of Table X

Source: Natural Sciences and Engineering Research Council of Canada, Information, Dec. 2, 1983.

TABLE 4.1
(page 2)

Industry	Project	Grant ($)
Mineral Fuels	Fossil fuel potential of carboniferous pull-apart basins	122,769
Paper	Fluidized bed recovery of Kraft black liquor	31,000
Primary Metals	Optimization studies of steel plant processing furnaces & vessels	73,352
Transp. Equipment	Rotary engine developments	41,589
Electrical Products	Spectroscopic studies, battery electrodes and electrolytes	25,595
Petroleum & Coal	Flocculation selective des fines de charbon	31,480
Chemicals	Gas chromatograph (equipment)	23,226
	Novel catalytic process for synthetic fuels and chemicals	43,000
Construction	Computer simulation and retrofit strategy for existing houses	47,620
Electric power & gas	Study of some optical problems in the separation of deuterium from CF3 H/CF3 10 using a TEA-CO2 laser	39,750

Assuming, to stay on the conservative side, that a success rate of assignability of 33 percent could be achieved (rather than the 43 percent rate actually attained in the sample), then about $9 million of this batch of grants worth $28.1 million could be allocated to specific industries. If we take the $246 million that NSERC is budgeted to give out in grants in 1984-85, then one-third of this amount, potentially assignable, represents $81 million. This, in turn, is equivalent to about one-third of the $259 million of R&D funded by the federal government in the business enterprise sector - a not inconsiderable amount.

CHAPTER 5

UPSTREAM RESEARCH BY COMMERCIAL SUPPLIERS

General Observations

Suppose that Canadian researchers working for the Forestry Service of Environment Canada develop a new variety of a fast-growing poplar. The federal service then transfers the cuttings from these higher-yield trees to provincial nurseries which multiply them and then sell them to all comers at recovery cost. The word "recovery" is stressed to exclude any notion of monopoly profit on the part of either level of government. Among the buyers are pulp-and-paper companies with their own stands of timber or forestable land. On the justifiable assumption that poplar softwood can be used in paper manufacture, it is more than likely that its use will lower the costs of paper production. One can indeed speculate that this was the researchers' prime intention and the funders' prime consideration.

Suppose, to take another yet allied example, that a Canadian logging machinery manufacturer (more likely, a division of a machinery manufacturer such as Dominion Engineering) assembles a specialized machine destined to harvest poplars. This innovation is capable of twice as rapid cutting as existing machinery; however, its seller prices it in such a fashion that its employment by the loggers does not lower cost by one-half but only by one-quarter. Despite some exploitation of the temporary monopoly power by the innovator, the profitability of this new piece of logging capital equipment will easily exceed that of the previously employed machinery.

In both examples we have instances of upstream suppliers deliberately setting out to provide more efficient inputs to their customers, while not taking away all the advantages of the innovative supplies through monopoly pricing. Supply-side innovative efforts are generally more the rule than the exception. Such efforts are also typically deliberately encouraged by customers, are stimulated from the demand side. We can easily imagine representatives of the pulp and paper industry encouraging the Forestry Service to find higher-yielding varieties of softwood and timberland managers cooperating with logging machinery manufacturers on improved equipment. (For a thorough airing of supply and demand influences see D. Mowery and N. Rosenberg, "The Influence of Market Demand on Innovation: A Critical Review of Some Recent Empirical Studies," Research Policy, 1979, pp. 102-153).

Can it be therefore said that a firm's or an industry's technological intensity resides solely within its own walls? Or should we also take account of its receptivity to suppliers' suggestions or indeed of its interventions with the suppliers of its capital equipment or other inputs?

Those who would argue against this widened notion of TI would suggest that either the receptivity or the active stimulation of the industry to upstream innovation depends critically on the amount of research carried out within the industry or, to put it differently, on the relative amount of qualified scientists and engineers employed in the industry. There would thus be no need to go to more aggregate measures of TI. At the limit it could be argued, as the National Research Council does (NRC discussion paper No. 23, December 1982), that TI should be defined in terms of the proportion of technical people employed by the industry in total rather than just in R & D.

This is a perfectly plausible position, susceptible to empirical verification, provided that it is safe to equate formal education with on-the-job experience. The crucial aspect is undoubtedly the innovation-absorption capacity of the industry. It would seem -- at least at first look -- that such capacity is at least as high in Canadian farming, a sector mostly manned by aging people without formal technical education, as in, say, metal fabrication.

The case <u>for</u> including upstream suppliers' R & D in calculating an industry's TI needs clarification before support. "<u>Whom</u> do we mean by suppliers?" is the first necessary question. Is it the first-round upstream suppliers only or should one go even further up? The issue is essentially one of the strength of the pull of demand that the industry examined exerts upward, such as: are the conditions in the paper industry so buoyant that the logging machinery suppliers are motivated to demand specially adapted microprocessors from the electronics industry? This writer cannot see, as of now, any satisfactory, that is empirically-based, answer to this question. What shall be done, therefore, is to examine the concept of TI under the immediate-suppliers and all-ascending suppliers assumptions.

The second issue for elucidation is "<u>How</u> do we measure the proportion of the supplier's research that should be allocated to the customer industry?" Terleckyj, the pioneer in measuring intermediate (i.e., upstream) research inputs, chose a simple method: allocate such proportion of R & D carried out in industry A to industry B as corresponds to the proportion of sales of A to B (Nestor Terleckyj, Effects of R & D on the Productivity Growth of Industries, National Planning Association, Washington 1974). Others have followed him.

We shall now take a look at the first-round or immediate-supplier R&D component of TI. For reasons explained elsewhere, we exclude from consideration publicly funded R&D performance on behalf of the industry by government or universities. We may agree, provisionally, that where only this first-round component is included, we deal with OWN-INTENSITY TI, as indicated in Figure 1, since here the pull of the demand side is presumed the strongest.

Immediate-suppliers' Intermediate Research Inputs

The procedure for calculating the research content of inputs purchased from immediate suppliers is perfectly straightforward. To quote Terleckyj (p. 56):

> In calculating the amount of R&D (embodied in purchased goods) bought by industry B from industry A, the sales of industry A to industry B are taken as a ratio to total sales of industry A and multiplied by the R&D expenditures of industry A. The same procedure is used to obtain the amount of R&D purchased by industry B from any other industry with the summation of these purchases yielding industry B's total purchased R&D.

The following formula summarizes the procedure:

$$\text{RD to A from } U_1 = (\text{Sales } U_1 \text{ to A})/(\text{Sales } U_1) \times \text{RDU}_1 = k_1$$

$$\vdots$$

$$\text{RD to A from } U_n = (\text{Sales } U_n \text{ to A})/(\text{Sales } U_n) \times \text{RDU}_n = k_n$$

and $\sum_{i=1}^{n} k_i$ = industry's A total immediate intermediate input of R&D from industries U_1 to U_n.

Industry A's "very-own" plus immediate intermediate R&D intensity is then

$$(RD_A + \Sigma k_i)/Sales_A$$

Table 5.1, which conceals a larger dose of tedious effort than meets the eye, gives some evidence of first-round upstream R&D inputs to two 3-digit SIC industries, pulp and paper and pharmaceuticals. Note that just first-round suppliers' R&D is almost two-thirds (62.3 percent) of all intramural research undertaken by the pulp-and-paper industry, whereas immediate upstream research contributes but little in the case of pharmaceuticals.

TABLE 5.1

First-round Upstream Total and R&D Inputs
of the Three Largest Suppliers to Pulp & Paper and
Pharmaceutical Industries in 1976
in Millions of Dollars

Pulp & Paper		Pharmaceuticals	
Total Inputs (Purchases)			
Agric., forest., fish.[1]	$879.2	SIC groups 30, 32, 35-43	$192.3
SIC Groups 30, 32, 35-43	823.8	Chemicals	55.2
Wood-based, printing (excl. pulp-paper)	566.6	Wood-based	27.9
R&D Inputs			
Ag., forest., fish.	$14.4	Chemicals	$ 0.6
Chemicals	2.6	Ag., forest., fish	0.1
Paper and allied (excl. pulp-paper)	1.6	Paper and allied	0.1
Total R&D Purchased from First-Round Suppliers			
	$21.8		$ 0.9
Total Intramural (Very-own) R&D			
	$35		$27

[1] 2-digit industries aggregated where separate R&D outlays not available.

Sources: R&D data from Science Statistics Centre, Statistics Canada and MOSST, SS-83-3, Table 4. Total inputs from special tabulation for author by input-output section of Statistics Canada.

The prime theoretical justification for including immediate suppliers´ R&D into an industry´s TI has already been discussed: it is the mutual economic (supply-demand) interaction between the two parties. The principal empirical justification are the results of Terleckyj´s study of productivity change in the US: there is a significant positive influence on total productivity of suppliers´ R&D, but no statistically detectable influence of own R&D.

The reservations one might have regarding the approach are again both theoretical and practical. The attribution, proportional to sales, of a supplier´s R&D to his customer rests on the assumption that most of the vendor´s R&D is oriented toward the creation and improvement of products for sale rather than towards the development of cost-reducing production processes for use <u>within</u> the seller´s firm. While this is undoubtedly true in the US -- a figure of 70%-80% of all industial R&D being new-product R&D is commonly cited -- it may not hold in Canada. Canadian industry, insofar as it is more primary-resource oriented than its southern counterpart, is likely to spend a larger proportion of its R&D budget on process development. The only Canadian data we have on this issue come from five industries, of which two are resource-oriented and three are of the standard manufacturing kind (telecommunications equipment, electrical industrial equipment, plastics; smelting and refining, crude oil exploration and production). The three standard manufacturing industries surveyed indicated between 70 and 80 percent of their innovations being product innovations; the two resource-based industries reported between 80 and 90 percent of their innovations to lie in the process development area (De Melto et al., Economic Council of Canada Discussion Paper No. 176, October 1980).

The second weakness of the approach, again somewhat peculiar to Canada, is the fact that sales or input data obtained from the input-output tables include imports, comparatively a very large percentage in our heavily trade-oriented economy. This is due to the collection of the basic data for the input-ouput tables: the individual census establishments (plants, production centres) report all purchases of commodities to Statistics Canada without making a distinction between imports and domestic purchases.

While it now appears in principle possible to tabulate imports of a commodity, such as chemicals, by purchasing domestic industry (Canadian Imports by Domestic and Foreign Controlled Enterprises, Statscan 1978, Cat. No. 67-509), officially published statistics are not yet available. Thus the normal procedure would be to use the R&D content coefficient of domestic suppliers as the appropriate coefficient to assign to all of the inputs of chemicals into a buyer industry. Yet it is quite possible that the embodied R&D differs substantially between imported and domestic suppliers of chemicals. Table 5.2 illustrates the point.

TABLE 5.2

Two Largest Suppliers of the Canadian
Rubber and Plastics Industry in 1976 and
Their Research Intensities (RD/Sales)

Industry	Sales to Rubber, Plastics	Research Intensity	
		Canadian 1973	US 1975
Chemicals	$595 Million	2.5%	3.2%
Textiles	120	0.2%	0.4%

Sources: Sales-special tabulation prepared for author by input-output section of Statistics Canada; research intensities - MOSST Background Paper No. 5, Table 2, 1978.

The two largest suppliers to the two-digit SIC rubber and plastics industry in 1976 were chemicals and textiles. Yet the direct or very-own R&D intensities of Canadian and US chemicals and textile industries differed considerably. One has to remember the substantial -- indeed one of the highest in the world -- trade intensity of the Canadian economy and the fact that over two-thirds of the trade is with the United States to realize the considerable distortion that the use of domestic input intensities may occasion in the calculation of embodied, first-round purchased R&D content.

All-upstream-suppliers' Intermediate Research Inputs

Since the major economic interest in technology, and by extension in R&D, is not in "das Ding an sich" but in their effects on productivity, that measure of technological or R&D intensity should be preferred which explains best their influence on productivity. Accumulating US results (F.M. Scherer, "Interindustry Technology Flows and Productivity Growth," Review of Economics and Statistics, November 1982, 627-634) show unambiguously the superiority of the [very-own plus all-upstream R&D] concept in the statistical explanation of productivity change. In Canada, the results are not as straightforward. Nevertheless, it seems imperative to discuss the notion of input-embodied R&D traced through immediate as well as higher-order suppliers.

"The trick is to expose and capture all of the R&D technology flows that may, directly or indirectly, stimulate productivity growth". This quotation from Postner and Wesa (p. 50,) can serve as an introduction here. In the immediate-suppliers approach discussed above the representation of the R&D flows is shown in Figure 3, Panel A. However, a truer representation of commodity flows -- with R&D embodied -- takes into account a so-called "cycling" process, illustrated in Panel B with a three-industry economy.

FIGURE 3

Inter-Industry Commodity Flows

Panel A

$$\begin{tikzcd}
U_1 \arrow[dr] & U_2 \arrow[d] & \cdots & U_n \arrow[dll] \\
& A & &
\end{tikzcd}$$

Panel B

$$\begin{tikzcd}
& A \arrow[dl] & \\
U_1 \arrow[rr] & & U_2 \arrow[ul]
\end{tikzcd}$$

(Arrows represent flows of R&D embodied in purchased inputs)

The exchange follows in the direction of the arrows. The Terleckyj measure would simply take the R&D performed by supplier industry U_2 and multiply it by [Sales of U_2 to A/Total Sales of U_2] to arrive at the (immediate) intermediate input of U_2's R&D to A. Yet industry U_2 brings inputs containing R&D from industry U_1 and U_1 buys inputs from industry A, which in turn receives inputs from U_2 and so on. It is clear that a measure which recognizes this cycle will yield a higher intermediate R&D content for industry A than the Terleckyj measure. Input-output analysis enables us to calculate this broader measure.

Let A be a matrix of input-output coefficients

X be the vector of industry outputs

Y be the vector of final demand for the products of each industry.

The fundamental relation of I-O analysis states that

$$X = AX + Y \longrightarrow$$

$$X = (I - A)^{-1} Y$$

where I is an identity matrix.

Now let R be the direct (i.e., very-own) R&D input requirement vector for the economy, where element _i_ represents the R&D required by industry _i_ to produce a unit of output (Hartwick; Postner and Wesa):

R = [RD Industry 1/Output Industry 1,...

RD Ind n/Output Ind n]

RX = total R&D requirements of the economy

then

$R(I - A)^{-1}$ is the vector of gross (own plus intermediate) R&D coefficients

and $\quad r_n(I-A)^{-1} - r_n$

is the intermediate R&D input vector, to be called s.

Now note that

$$(I - A)^{-1} = (I + A + A^2 + \ldots + A^N + \ldots)$$

which is the sum of a convergent series. The Terleckyj measure of intermediate R&D input is similar to the second equation above. It is

$$r_n(I + A) - r_n$$

which omits the terms $A^2 + \ldots + A^N + \ldots$ It is in this omission that the Terleckyj measure ignores the cycle of R&D inputs throughout the economy.

An analogy can be offered in the consumption function of a simple macroeconomic model:

$$C = a + bY$$

where b is the marginal propensity to consume and Y is national income. The total effect on national income of a change in exogenous spending by government, G, is

$$(1 + b + b^2 + \ldots + b^n + \ldots)G$$

while the first-round effect is simply

$$(1 + b)\ G$$

The example is given to show that input-output analysis accounts for the multiplier effect of R&D throughout the economy and in this sense leads to a more complete inclusion of the technological intensity of an industry's output which goes to final demand, that is, of an output that is either exported or consumed, but not recycled again.

Yet this "final-demand" orientation of TI of an industry which would comprise all of the upstream R&D efforts, while useful in pointing out all the interdependencies between industries, has also a drawback. It neglects the active interdependence, a demand-supply interplay, which seems important when considering the concept of TI, a concept which implies at least some active receptivity on the part of the embodied-R&D recipient.

Another drawback of the input-output based total-upstream measure of embodied purchased R&D is, as has been already mentioned in connection with the Terleckyj measure, the presence of imports. To illustrate this more clearly we refer to the study of Hartwick and Ewen, one of the only two Canadian examinations of the so-called technology flow matrix (J.M. Hartwick and B. Ewen, "On Gross and Net Measures of Sectoral R&D Intensity for the Canadian Economy," Queen's University Dept. of Economics Discussion Paper No. 547, 1983).

Hartwick divided A, the matrix of input-output coefficients, into A^d and A^f, where an element of matrix A^d is the dollar flow of domestic commodity $\underline{i}$ required to produce a dollar of commodity $\underline{j}$ and an element of A^f is the dollar flow of foreign commodity $\underline{i}$ required to produce a unit of commodity $\underline{j}$. A^d and A^f are derived from A by use of a vector F whose $\underline{i}$-th element is the ratio of imports of industrial product $\underline{i}$ to the amount of industrial product $\underline{i}$ used domestically.

A^f is calculated by multiplying each element in column $\underline{i}$ (i = 1 to n, where n = number of industries) by the i-th element of F. A^d is calculated in a similar manner except that instead of F, (C - F) is employed where C is a vector of ones. Note that $A = A^d + A^f$. Now define A^d/A as the element-by-element division of the two matrices A^d and A^f and define A^f/A in the same way.

Hartwick, given the absence of precise information on the import content of inputs, has to assume that

$s^d = s\ (A^d/A)$ and $s^f = s(A^f/A)$

where s^d is equal to the upstream R&D that is accounted for by domestically produced intermediate inputs and s^f is the intermediate research in foreign-produced inputs.

The problem here is that very-own or direct Canadian R&D intensities are used to calculate all - i.e. both imported and domestic - intermediate or upstream R&D content, designed previously as $\underline{s}$. To multiply $\underline{s}$, the intermediate R&D content of a commodity, by the fraction of foreign good embodied in a unit of Canadian output, in order to arrive at a figure for foreign R&D embodied in purchases is to assume necessarily that the products of foreign and domestic "parallel" industries have identical R&D intensities.

The correct procedure to follow would be the following. Assuming for simplicity that Canada trades only with the US, calculate first with the help of American I-O tables the vector of total output content or gross R&D embodied in American exports to Canada. With this vector and with the A^f matrix follow then the basic I-O procedure to arrive at a figure for the vector of foreign technological inputs into Canadian industries. Add this to the vector of domestic technological inputs to arrive at a truer measure of the technological intensity. The remaining flaws are the absence of information on the precise amounts of imports from the US to the particular domestic industry and the fact that some large foreign suppliers of Canada, such as Japan and the UK, would be omitted.

While Postner and Wesa (1983) apparently used the same I-O approach to derive final output content intensities, they do not publish them as their attention is focused on productivity analysis. Hartwick's preoccupations were, however, closer to those of this study, and we come back to his results in the next chapter.

CHAPTER 6

THE TI CONCEPT AND ITS TWO DEFINITIONS

If the reader has worked his way through the preceding chapters he will undoubtedly have come to the conclusion that whether one or the other definition of TI is agreed upon and used matters less than how many components are included in each.

Those published investigations which result in or imply definitions of TI, when they go beyond very-own or direct research, include upstream suppliers´ R&D but nothing else. This, however, represents already substantial progress. On the Canadian scene this progress is illustrated in Hartwick and Ewen´s Queen´s University Discussion Paper No. 547 mentioned in the previous chapter. While omitting, as far as can be judged, the public sector in which much R&D is going on, they found that in 29 business sectors of the economy -- averaged over the years 1973, 1975, 1977 and 1979 -- the mean direct-research TI was 0.0099, or almost one percent. When total "cycled" upstream suppliers´ research was included, as described in chapter 5, the mean TI percentage doubled to 0.0197, or almost 2 percent.

But does the inclusion of all-suppliers´ upstream research yield new insights? More precisely, does the ranking of the sectors change as one goes from "net" research intensity to "gross" research intensity, to use the adjectives employed by the two investigators? Hartwick and Ewen ran a corelation between the two intensities and did not find it significant at the 5 percent level of confidence, once the outlier Transport Equipment sector was excluded. In their words, "the net measure of research intensity may not necessarily be a good indicator of the intermediate research embodied in a commodity". The answer then is that the ranking may indeed change substantially as one goes from net to gross intensity. Clearly, the traditional very-own (direct) research definition is substantially different from a definition which is focused on R&D output content, at least when all-upstream-suppliers' research is reckoned in.

We cannot say this with certainty for the case when only the immediate-upstream-suppliers' R&D is counted in. We have estimated the embodied research from immediate suppliers in only two sectors, drugs and pulp and paper. As table 5.1 indicated, first-round suppliers added only $0.9 million to the drug industry's $27 million performed R&D in 1976, but they added $21.5 million to the paper industry's performed R&D in that year. This limited evidence cannot settle the issue, but it is enough to indicate that further research in this direction would be of value.

We believe, as already pointed out, that the inclusion or exclusion of first-round suppliers' R&D in the own-intensity TI definition cannot as yet be clearly supported. (It seems to us that given the usually interactive symbiosis between suppliers and customers, first-round suppliers' research should be so included and so it is positioned with lesser emphasis in the first column of Figure 1). However, it is quite obvious that invisible R&D imports and government and university research assignable to SIC sectors do belong in the own-intensity definition -- and so perforce also in the all-encompassing output content concept.

While the contribution made in this area by the MOSST No. 3

background paper was substantial, nobody else -- in Canada or abroad -- has pursued the line of reasoning which leads to the concept of imported invisible R&D. As was pointed out in chapter 2, the MOSST estimates for 1974, 1975 and 1976 indicated that such invisible imports were more than two-and-a-half times higher than the domestically performed R&D in the industries concerned, industries which accounted for the bulk of Canada's business enterprise R&D. Once again our more limited estimates, which covered drugs, paper and transportation equipment sectors in 1981, are insufficient to confirm that such a large amount of invisible R&D persists into the eighties; nevertheless the 1981 figures which represent 26 percent of domestic R&D for the paper sector, 30 percent for drugs, and more than 200 percent for transport equipment point to continuing heavy invisible importation.

As far as is known there are no published estimates in Canada or elsewhere of the volume of research in natural and engineering sciences undertaken intramurally by governments and universities for the direct benefit of specific industries. Our attempt at the estimation of assignable federal government R&D has not resulted in any "globally projectable" figures as in the case of invisible R&D imports. (It should be noted, nevertheless, that in 1982 all Canadian governments and provincial research institutes performed $1.2 billion worth of research out of a total GERD of $4.6 billion laid out in natural sciences and engineering). However, it did show quite clearly in several instances that such estimation is possible and would be more generally feasible if government departments committed themselves to what might be called assignability disclosure. Somewhat unexpectedly, a large number of NSERC's grants to university researchers was of clear benefit to specific industrial sectors. A perhaps imprudent attempt at projection resulted in a figure of $80 million in fiscal year 1984-85 as being NSERC's contribution to assignable university R&D.

The original research plan of this project envisaged a heavier focus on the assembly of complete intensity data for several industries and also some investigation of a possible additional component of intensity, R&D performed in "technologically adjacent industries". It rapidly became apparent that satisfactory data for invisible R&D imports and foreign suppliers' research could only be generated by special Statistics Canada tabulations; budget and time limitations did not allow for this. Similar factors precluded also the investigation of the spillover component coming from adjacent industries. However, while this project was going on two studies -- by Hartwick & Ewen and Postner & Wesa -- appeared and threw light on the concept of technological intensity in Canada. H & E gave solid estimates of own - and own-plus-suppliers' R&D intensity. P & W first estimated R&D stocks and then, using a similar input-output framework as H & E, provided estimates of technological flows and their effects on downstream industries.

Thus the contention in our original research proposal that suppliers' research should be included in Canadian R&D effects analysis was handsomely taken care of and we could devote more of our attention to looking into the other components of intensity. Several implications of our findings set out in the following chapter; here the final word should be about the possible differences between the two concepts of TI that were put forward.

The findings of this study suggest that the distinction between the traditional and recent definitions of technological intensity does not go far enough to be truly useful from a public policy standpoint. The traditional definition of TI rests on the very-own (direct) R&D/Output ratio, while recent overt or implied definitions augment that ratio by the R&D content of purchased inputs. As was argued, the recent definition, while representing solid progress, does not go far enough because it omits the benefits of research made available to the industry concerned from foreign affiliates, from government and from university. When sufficient data is available to fill the gap in as reliable a manner as when calculating direct or suppliers' R&D intensities (which is not saying very much), then it will be possible to make the debate on the stimulation of technology better informed.

The debate regarding technology is always a debate about public intervention, since the general presumption is that there is not enough technology in our industries. It is only when we get a good notion of the existing level of technology present in an industry with the help of a sound concept of TI that we can make a useful diagnosis. The diagnosis should inform us as to the adequacy or otherwise of TI and as to which component of TI is in need of specific attention.

It is only after the completion of such a diagnostic exercise that the distinction between own- and output-content intensity can come into its own, when it is judged that in a specific case only suppliers are really capable of delivering the needed technology to technically stagnant clients.

CHAPTER 7

SOME IMPLICATIONS OF THE STUDY

The constant preoccupation of Canadian public policy with the alleged insufficiency of the technological performance of our industries leads to a frequent recourse to the notion of technological intensity, most often taken to be synonymous with R&D intensity. The public handwringing usually starts by demonstrating that this or that Canadian industrial sector is less tech-intensive than its relevant foreign counterparts.

It has been shown elsewhere that mere comparisons of R&D intensity without the use of a broader economic framework (an econometric model of R&D intensity determinants) are to be avoided (Palda and Pazderka, 1982, op.cit.). The theme of this investigation is in a sense more modest, yet more fundamental: technological intensity is more than just the direct R&D of an industry. However, in this small open economy we are bound to check first impressions of our performance by making international comparisons and so to say that TI should have a wider meaning than just very own R&D intensity is not enough. It must be shown that even when the definition of TI is enlarged, a particular Canadian industry's intensity is still lower than that of a relevant counterpart abroad.

This means in practical terms that it must be shown, in the interest of a sounder comparison, that Canada's industry benefits differentially from its foreign countepart from invisible R&D imports, government intramural research, university research and R&D content embodied in imported supplies. This is the first implication of our investigation.

Our impression is that there are some substantial differences to be found in Canada on the TI scene with respect to the first two phenomena. In Canada, first of all, more than anywhere else in the OECD universe with the exception of Australia (and Austria and Belgium?), industry benefits from free access to the research of foreign affiliates -- simply because foreign ownership of industry is so high.

In Canada, as well, the business enterprise sector "performs" a smaller share of GERD than in most comparable OECD countries. Conversely, government and universities perform a higher share. This is illustrated by the few examples listed in Table 7.1, which is representative of more comprehensive OECD reports over many years. If the proportion of government intramural and university research undertaken for the direct benefit of industry is not substantially different abroad, then it can be presumed that comprehensive measures of TI would place Canadian private industry in a more favourable light.

TABLE 7.1
R&D Perfomance Outlays by Sector
in Canada, France, UK, Germany, Netherlands
in the Early 1980´s
(in percentages of GERD)

Sector of performance	Canada (1982/3)	France (1981)	UK (1981/2)	Germany (1982)	Netherlands (1981)
Business enterprise	50.3	58.9	62.9	69.7	53.3
Government	24.6	23.6	..	13.8	20.5
Higher education	24.4	16.4	..	16.0	23.2
Private non-profit	0.7	1.1	..	0.5	2.8
GERD	100.0	100.0	100.0	100.0	100.0

Source: OECD, Science Resources Newsletter No. 8: Paris, 1984, Table 1.

The <u>second implication</u> of this study is then that we need a better grasp on information about invisible imports of R&D by relevant foreign industries and on the nature of government intramural research for the benefit of industry in comparable foreign countries. However, a more immediate and practical consideration is the elaboration of reports on Canadian governmental (federal <u>and</u> provincial) intramural research assignable to industry. This is needed before foreign comparisons can be made.

And so the <u>third implication</u> of this investigation that government departments, perhaps following a pilot study, should shed the anonymity of their research reporting and make an effort at assignability. This would greatly clarify the issues with which public policy must wrestle.

The <u>final implication</u> that merits listing is that a statistical reporting system on TI component by component would facilitate the targeting of invervention: increase or decrease of subsidy direct to the industry in question, pressure on foreign subsidiaries, bigger or smaller government intramural R&D budgets and university grants; or subsidies to domestic suppliers if it is found that there is a substantial difference between the expanded own-intensity and content-intensity definitions.