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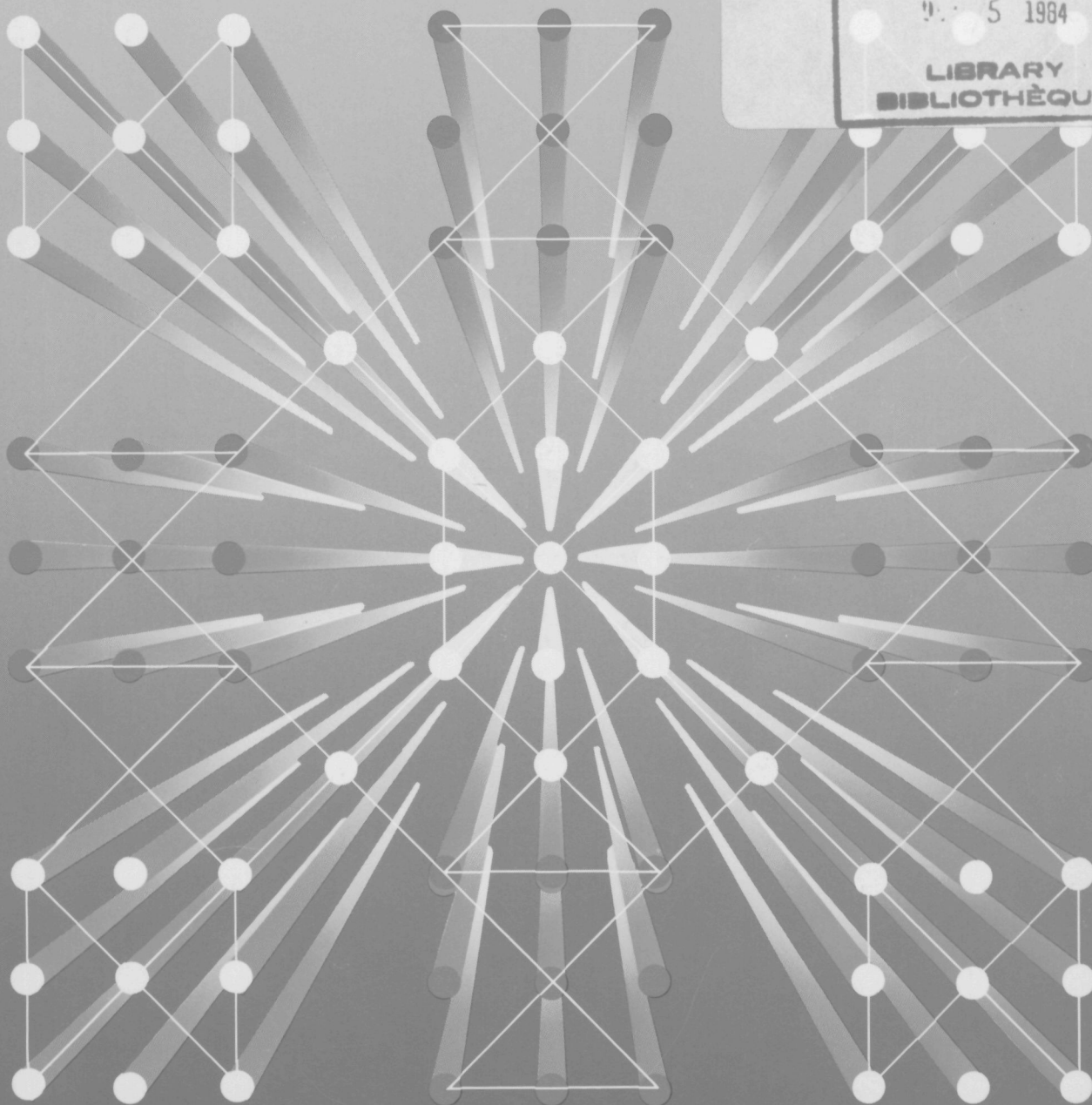
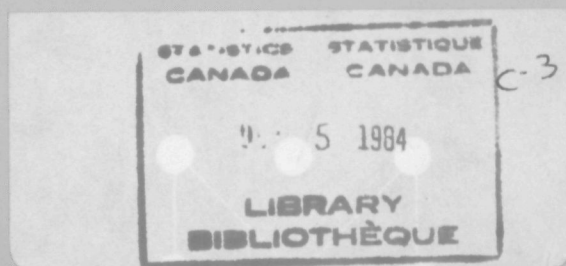
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# Technology and Commodity Trade



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**Statistics Canada**  
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# Technology and Commodity Trade

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- amount too small to be expressed.
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## PREFACE

This paper examines the use of commodity trade statistics as an indicator of science and technology. It presents a historical perspective on the concepts, examines the theoretical, statistical and definitional foundations of the indicator, and outlines existing statistics and their uses.

Science and technology indicators may be defined as statistics which measure quantifiable aspects of the creation, dissemination and application of science and technology. As indicators, they should help to describe the science and technology system, enabling better understanding of its structure, of the impact of policies and programs on it, and the impact of science and technology on society and the economy.

**Technology and Commodity Trade** is one of a series of background papers on science and technology indicators to be published by Statistics Canada. The purpose of the series is to describe the theoretical development, limitations and application of various statistics suggested as indicators of science and technology.

Current indicators of Canada's scientific and technological activities include:

- expenditures on research and development;
- federal government scientific activities;
- personnel working in science and technology;
- Canadian research output (citations);
- Canadian patented inventions;
- international payments and receipts for technology;
- trade in selected commodities.

Statistical tabulations of the indicators will be released in **Science and Technology Indicators**, Catalogue No. 88-201, an annual summary; **Industrial Research and Development Statistics**, Catalogue No. 88-202 (Annual); **Resources for Research and Development in Canada**, Catalogue No. 88-203 (Annual); **Federal Scientific Activities**, Catalogue No. 88-204E (Annual); and in a monthly service bulletin, **Science Statistics**, Catalogue No. 88-001.

A list of the proposed background papers is included at the end of this publication. These papers represent the opinions of the authors and do not necessarily represent those of Statistics Canada. Comments are invited and should be addressed to Karen Walker of the Science and Technology Statistics Division.

This paper has been prepared by Ernst Kneisel of A.D. Revill Associates Ltd.

Martin B. Wilk  
Chief Statistician of Canada



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## INTRODUCTION

Trade in "High Technology" Commodities is a statistical measure of international trade in those commodities defined as having a "high content of advanced technology". The classification of commodities varies among the agencies producing this data. Commodity trade is one of a number of indicators which together are used to describe a nation's level of scientific and technological advancement as it affects its industrial competitiveness.

The international flow of proprietary technology is shown schematically in Chart 1. This chart illustrates the functional relationships among research and development (R&D), innovations and know-how; and the various alternative paths by which innovations and know-how may be exploited by the firms which own or control them.

The upper part of the chart shows the options available to a firm in Country A which successfully invests in R&D and develops a process innovation. The vertical flow directly downward is the primary, conventional route towards the manufacture of the final or end product for the domestic market. Double lines are used to distinguish it as the historic conventional path.

The secondary and alternative routes, however, might be any of those shown in the boxes to the right. These routes vary from keeping the process innovation at home and exporting the final product to exporting the know-how for the new process via one or more of the suggested procedures.

Another firm, in Country B, has several alternatives to consider in acquiring the innovation. It can invest in R&D to develop a comparable innovation; it can import and resell the new commodity; engage in prototype copying; purchase the know-how and capital equipment; buy a turn-key plant; or enter into a joint venture with the innovating firm.

Less developed countries are generally in the position of Country B while the United States and Japan are pre-eminently in the position of Country A.

Thus R&D, importing and exporting, licensing, copying, joint ventures and direct investment can all be seen as possible routes to the advancement and exploitation of technology at home and abroad. The route selected depends on a number of variables in both countries - including, on the part of governments, protectionist versus free trade policies, closed versus open-door-to-investment policies - as well as the countries' general political and social climates. On the part of the firm, important factors in selecting the desired route of action include: competitiveness of the environment; the level of background knowledge and skills available in the work force of the recipient country; market conditions; and cost relationships.

Chart 1 can be directly related to known contracts and projects. An example is the sale of acrylonitrile technology by Standard Oil Company of Ohio (Sohio) to the Peoples' Republic of China.<sup>(1)</sup> The Chinese purchased from Sohio a complete turn-key package (including basic production facilities as well as additional plants) to produce intermediate products. It is expected that it will not be many years before China will be competing with the United States for exports of the end product in Far East markets, i.e., in Countries C and D. In this case, China chose not to invest in R&D nor to import the finished product but instead to buy outright the capacity to produce. Presumably both China and Sohio benefited, but the long-term prospect for U.S. exports appears to have diminished.

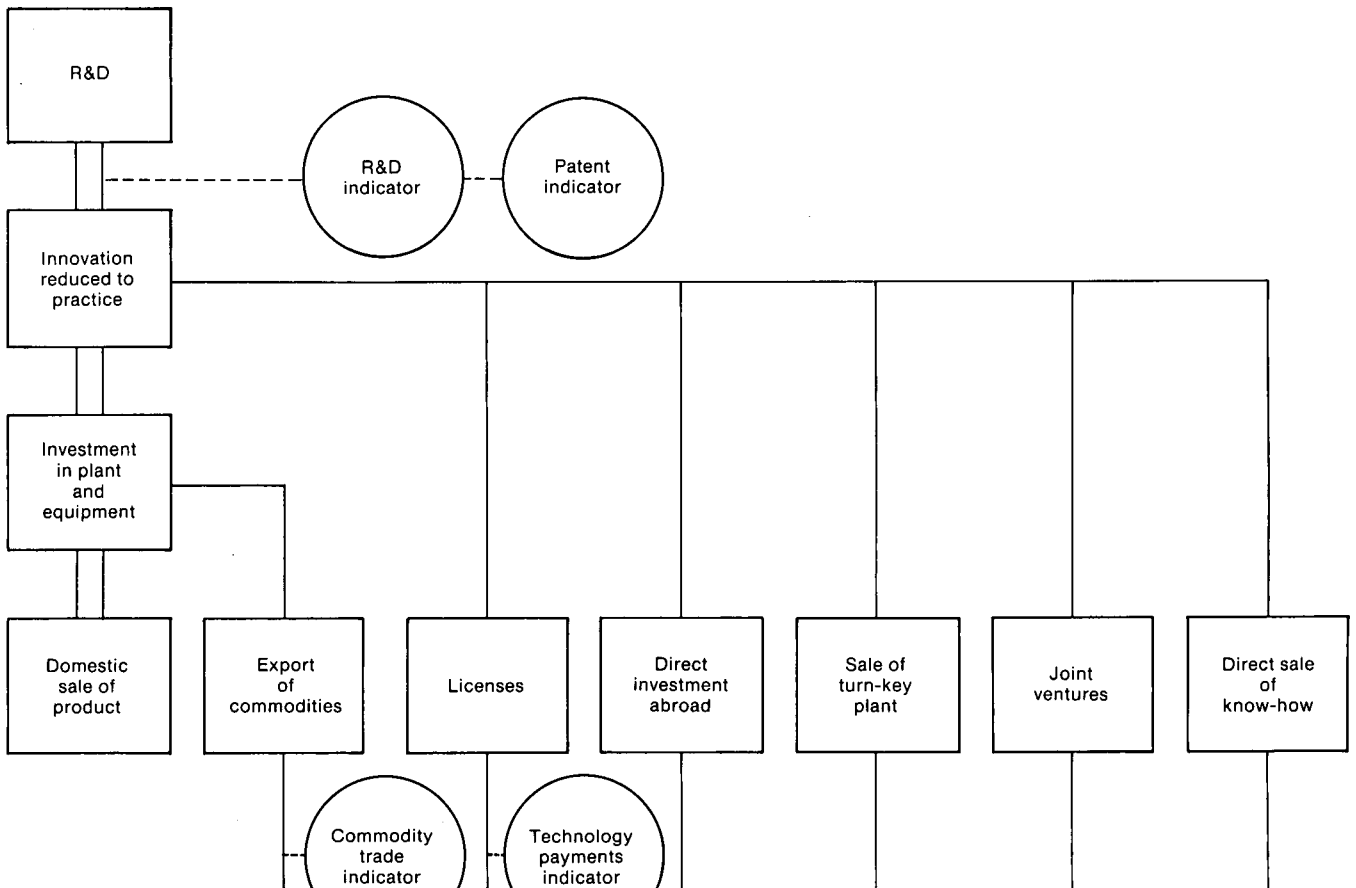
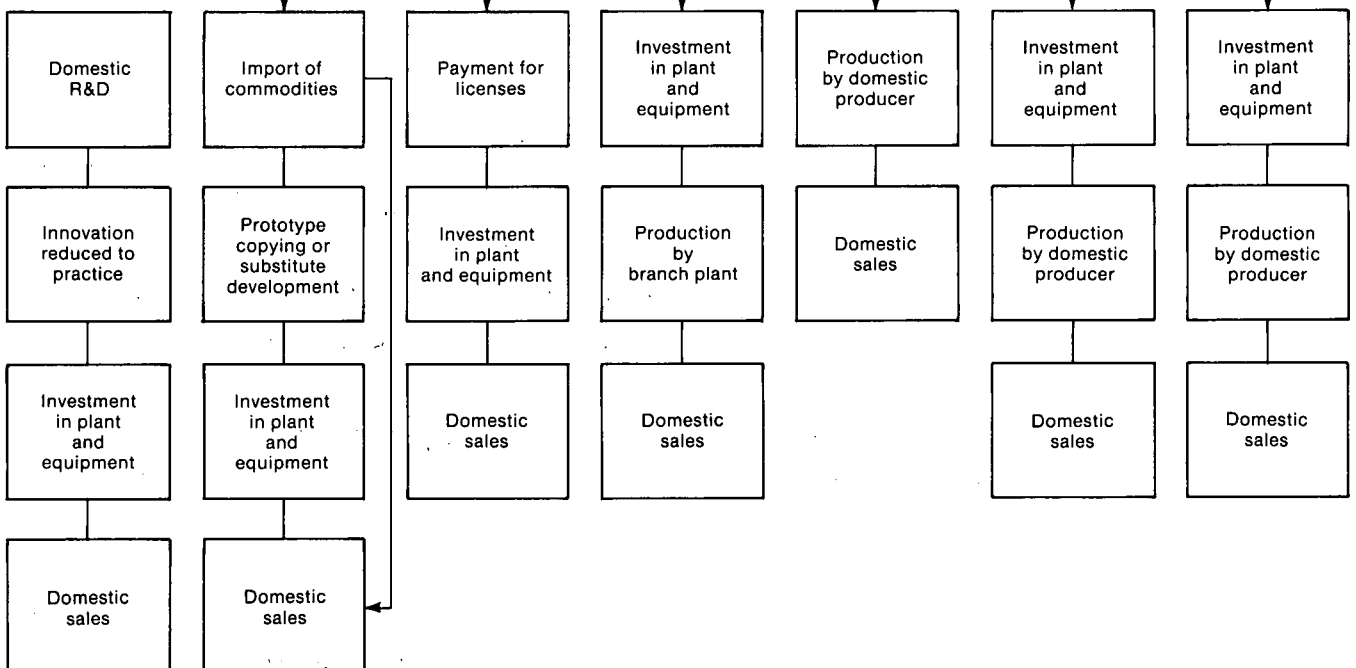
Clearly, imports and exports are only one of a number of methods for profitably exploiting technology internationally. Accordingly, to have a meaningful picture of a country's technological competitive standing, all methods must be examined simultaneously. This general viewpoint is well expressed by the National Science Foundation:

"Taken individually, sets of data generally are not sufficiently definitive in describing certain aspects of science and technology, but when considered together as multiple indicators of a phenomenon, these data sets permit more lucid comprehension and broader perspectives. And as indicators, they are indirect reflections of performance, behaviour, or status."<sup>(2)</sup>

(1) Baranson, J., **Technology and the Multinationals**, Lexington Books, D.C. Heath and Company, U.S.A., 1978, p. 130.

(2) **Science Indicators - 1980**, National Science Board, Washington D.C., 1981, p. vii.

Chart 1

**The International Flow of Proprietary Technology****Country A****Country B**

This paper will now proceed to provide historical background on the commodity trade concept. In Chapter 2, the definitional foundations of the trade in "high technology" commodities are examined. Chapter 3 outlines existing statistics and their uses by various agencies. Finally, the above discussions are summarized in Chapter 4.

This paper has drawn heavily on relatively few documents and lightly on a good many others. Those in the former category are:

**Canadian Science Indicators, 1983**, Statistics Canada, Catalogue No. 88-201, Ottawa, 1983.

**Annual review of science statistics, 1982**, Statistics Canada, Catalogue No. 13-212, Ottawa, 1982.

"Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", Note by the Secretariat, OECD, DSTI/SPR/83.13, Paris, 1983.

**Science Indicators - 1980**, National Science Board, Washington D.C., 1981.

A complete description of all reference material is provided in the Bibliography.

Personal interviews with the following authorities form the basis for some of the unattributed or statistically unsupported statements which appear in this paper, however, any errors are the author's responsibility.

A. Anctil, Vice-President, The SNC Group, Montreal.

A. H. Hamilton, Government Affairs Officer, U.S. Export-Import Bank, Washington D.C.

A. Zimmerman, President, Noranda Corporation, Toronto.



## Chapter 1

### A HISTORICAL PERSPECTIVE

For many years of the pre-industrial era a nation's "balance of trade" was considered the central determinant of its wealth and power. A "favourable" balance of trade, of course, indicated that the monetary value of the commodities exported was greater than the monetary value of the commodities imported over a specified period of time. A favourable trade balance implied that the country enjoying it had a net inflow of gold, which could almost always be translated into wealth and power. The policies designed to maintain positive balances, usually aggressive foreign policies, were known as "mercantilist".

Today, however, a country's balance of trade is no longer viewed as the international barometer of wealth and success; its "balance of payments" must be examined as well. One reason for this is that payments for various "invisible" items have become increasingly important over time. The invisibles which occasion external payments are especially important to Canada. Among the most stable and important of them are payments by Canadian subsidiaries to parent firms abroad (dividends, interest and capital repayments); expenditures abroad by Canadian travellers; and remittances to nationals of other countries by Canadians. These payments for invisibles have been sufficiently important over the last 10 years to constitute a major source of pressure on the Canadian dollar in spite of the fact that our balance of trade has been favourable.

The concept of a "balance of trade in high technology commodities" limits the aggregative balance of trade concept to those items which are judged to have a "high content" of advanced technology (the basis for that judgement varies for each statistical agency and will be discussed later). The broad implication of a positive trade balance in technologically advanced commodities is similar to the implication of the general balance of trade, i.e., a positive balance should augur well for a country's wealth and power. More specifically, a positive balance of trade in "high technology" commodities should tell us something about the state of advancement of a country's domestic technology. If a country's exports of such commodities exceed imports, it is evidence that it is ahead of those countries importing from it in the particular areas involved; and it is competing successfully with other exporters of these commodities.

Similarly, if imports of these commodities exceed exports, the implication is that the country's domestic industry is not competitive in this area. However, to the extent that the imports are of capital equipment, the subsequent improvement in the technological base may affect future balances.

Qualifying statements must be made with regards to the basis of the specific commodities traded and the high technology designation. For example, if large quantities of agricultural chemicals (a "high technology" commodity for some lists) are being exported, less is said about the state of advancement of domestic technology than if large quantities of mainframe computers are being exported. The chemicals may be considered high technology because of a high volume of research and development carried out by the industry but they have fairly limited specific use and have no impact beyond that use. On the other hand, the computer as a commodity embodies the high technology and furthermore it will almost certainly have a secondary impact through many industrial and business applications.

Qualifications concerning the underlying industrial organization or structure are also important. The stereotype of the industrial world which implicitly underlies the historically conventional interpretation of balance of trade statistics is described in the left-hand column of the following table. The contemporary realities (right-hand column) present a contrasting picture.

TABLE 1 Comparative Industrial Structures

Historic stereotype structure	Contemporary structure
. Industries generally are made up of many small competing producers.	. Industrial production is highly concentrated. Most industries' production comes from a small number of large firms, the operations of which are consolidated financially, and cross the lines of traditional "industry" boundaries.
. All competitive advantages are exploited internationally by means of exports of finished commodities.	. Competitive advantages based on technology may be exploited by any of the other routes shown in Chart 1, i.e., licensing, direct investment, direct sale of know-how, sale of know-how with plant and equipment directly or by joint venture.
. Trade between countries is relatively free of tariff and other barriers.	. Tariff and more importantly non-tariff barriers, have been responsible for reducing the importance of exports as a means of exploiting competitive advantages. This applies especially to technology based advantages compared to those arising from low resource or labour costs. The reason appears to lie in nationalistic goals of both self-sufficiency and technological advancement in various industrial sectors.
. Exports consist basically of finished products for sale in the importing country's consumer markets.	. More and more, exports consist of intermediate products, shipped by multinational firms to their subsidiaries abroad - either for fabrication and re-export or for fabrication and consumption in the importing country. In Canada's case 60% of commodity imports are occasioned by subsidiary firms' purposes from their external parent companies.(1)

(1) **Canadian Imports by Domestic and Foreign Controlled Enterprises**, Statistics Canada, Catalogue No. 67-509, 1979.

From this contrast between the conventional underlying assumptions and the contemporary realities it is recognized that, while exports and imports of "high technology" commodities are evidence of a country's state of technological advancement, the dollar volume may come under question. For example, when the exporter and importer are the same corporate entity, the element of competition may be fairly remote from the transaction, and a number of intra-corporate considerations may influence the terms and volume of the trade.

## Chapter 2

### A DEFINITIONAL FRAMEWORK

#### World Trade

The theory which explains favourable export trade balances in "high technology" commodities is based on the "product cycle theory", according to which an automatic temporary monopoly will result from the development of a successful new product or a new process. Thus, an innovating firm should enjoy a period of monopoly before imitations or substitutes for the innovation can be found. This applies both domestically and internationally and, so long as some degree of monopoly exists, the innovator clearly has a competitive edge in its markets. If the edge can be maintained through an extended growth stage, the innovator might well continue his advantage by being the first to achieve economies of scale.

In recent years, however, this theory has failed to describe the reality. According to a recent OECD paper on the subject,<sup>(3)</sup> multinational firms have tended to short-circuit the whole process by essentially sharing their monopolistic advantages with each other, especially when they leave the North American continent, thus obviating the high risks and costs of fighting each other as monopolist against competitors. The "sharing" referred to might take the form of a joint venture, a cross-licensing agreement or the trade or sale of know-how and patents.

This view is expressed also in the writings of J. Baranson, S. Gee and others (see Bibliography). Specific reinforcement for it can be found in an example by Baranson<sup>(4)</sup> in which 10 major data processing manufacturers are described as pooling their R&D efforts. We may assume that this will result in the sharing of the fruits of those efforts, i.e., the area of sharing is actually being moved to more basic levels.

The primary impact of this development on the indicative value of international trade in "high technology" commodities is reduction in the overall volume of trade in such commodities and in the absolute size of trade balances. Nevertheless, changes in the size and direction of the balance for any country will still provide a meaningful indication of each country's progress or regression in its level of productive technology.

According to the OECD paper the development of such "co-operation agreements" has resulted in world markets acquiring an "oligopolistic" character. Without entering into a discussion of oligopoly (competition among the few) the point should be made that it would fit contemporary usage better to refer to such agreements as taking place among participants in "shared monopolies". (This term was coined by the U.S. Federal Trade Commission to describe this type of competition.) Oligopolists are generally considered to be serious competitors on a price basis. Obviously, such developments can take place only in a setting of highly concentrated industry.

#### Classification Approaches

There are a number of approaches for classifying commodities by level of technology currently in use and in the process of development. The approaches are not mutually exclusive, but some indeed prove to be complementary.

##### **Approach 1 - Identification by Internal Industrial Data**

The most widely accepted method of classification involve the identification of "high technology" commodities by the first of the following three criteria:<sup>(5)</sup>

- R&D expenditures as a percentage of sales
- scientific personnel as a percentage of total personnel
- skilled personnel as a percentage of total personnel.

(3) "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", OECD, DSTI/SPR/83.13, Paris, 1983, p. 9.

(4) Baranson, J., **Technology and the Multinationals**, op. cit.

(5) "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", op. cit., p. 17 and F-1.

A fundamental problem with all three of these criteria is that, for most countries, the data are gathered on an industry rather than a commodity basis. This raises concern about the data collection process with regards to maintaining consistency from one industry to another and over time. The petroleum industry, for example, does a considerable amount of R&D - but this may have no impact whatsoever on the embodiment of technology in crude oil. In other cases, such as the television industry, the level of R&D spending or the proportion of skilled and scientific workers probably does have an impact on most of the "commodities" produced, i.e., the television equipment actually manufactured.

#### Criterion - R&D Expenditures as a Percentage of Sales

The criterion of employing product-related R&D expenditures to identify "high technology" commodities is used by the U.S. Department of Commerce and has been adopted by the OECD Secretariat. This method involves calculating the arithmetic mean of all of the product categories' individual percentages of R&D expenditures over product sales and identifying those categories above the mean as "high technology" commodities. The critical figure actually used was 2.36% of R&D to sales. The resulting OECD list of "high technology" commodities is reproduced in Appendix I.

This method is feasible only for countries such as the United States which collect R&D expenditures by product. Of course, as the OECD has done, any other country could adopt the U.S. list.

#### Criterion - Scientific Personnel as a Percentage of Total Personnel

According to the study last quoted, this particular criterion has not been widely used. This is probably because the results parallel the R&D expenditure criterion very closely. Nevertheless, the National Science Foundation employs this criterion in its analysis and is refining its use as a statistic. It would involve identifying industries for which the number of scientific and engineering personnel employed is above a certain percentage value of the total employed.

#### Criterion - Skilled Personnel as a Percentage of Total Personnel

The percentage of skilled personnel employed in the production of the commodities is generally not an acceptable criterion, at least by OECD authorities. It is considered too difficult a task to isolate skilled from unskilled personnel - except by wage rates. Wage rates, in turn, are seen to be subject more to economic and institutional factors than to purely technological factors. In any case, it and the preceding method both rank industries rather than commodities.

#### **Approach 2 - Identification by Correlation Techniques**

A second basic approach to identifying "high technology" commodities avoids the *a priori* selection procedure used above. Instead, it attempts to identify those export products which appear to be more dependent on technology than others. This is done by calculating the correlation coefficient between each country's market share of each product's exports and a number of explanatory, technology-related variables. The explanatory variables (in various applications of the approach) include the cumulative number of patents issued in connection with the product in the U.S.A.; R&D expenditures in the U.S.A.; capital/labour ratio of the sector; as well as a number of others.

Specifically, a study by Pavitt and Soete documented in the OECD paper performs product-by-product cross section regressions between the market shares of each country's exports and the shares of cumulative patents registered in the United States. As with all regression analysis, however, discovering a significant correlation between the variables does not imply that a causal relationship exists between them.

Nonetheless, one would expect on purely intuitive grounds, that patent shares and export shares should be functionally related to some extent at least. The taking out of patents in the United States might be said to indicate something about the level of technology of a country's exported commodities; and in turn, a high level of technology in the commodities could cause a high level of exports if that technology does actually make the commodity more competitive in world markets. By this reasoning, Canadian wheat exports, however competitive, would not show a high correlation with U.S. patents on wheat production; thus Canada's exports are not "explained" by patents, and therefore it is not judged to be a "high technology" commodity.



The list of "high technology" commodities determined by the regression method agrees reasonably closely with that of the U.S. Department of Commerce and the OECD. The OECD study considers the two approaches "complementary". This list can be found in an OECD sponsored study by Pavitt and Soete, LaCroix and Walker: "International Trade in High R&D-intensive Products", OECD, STIC/80.48.

### Approach 3 - The Rothwell Approach

In August 1980, the Directorate for Science, Technology and Industry of the OECD published a paper by Dr. Roy Rothwell of the University of Sussex entitled "Non-Price Factors in The Export Competitiveness of Agricultural Engineering Products". Dr. Rothwell has developed a novel approach to classifying commodities which does not rely on R&D expenditures as an indicator of high technology. Instead, he uses the unit value of the agricultural machines which are the subject of his study, and the number of patents issued on each type, as "proxies" to determine their relative technical sophistication. These results were confirmed by the opinions of users and potential users of the equipment.

This approach, which employs some interesting methodological innovations, is probably applicable only in a small number of industries. Those industries must, like the agricultural machinery industry in England, consist of numerous small independent competing producers. Unfortunately, very few such industries exist in the contemporary world. As Rothwell said, he would have to exclude tractors, "which largely avoids the complexity of multinational ownership of production: within Europe, outside tractors, market leaders in most areas are nationally owned companies, which is largely the result of a high degree of market segmentation in agricultural engineering products."(6)

A statistical problem with this approach concerns the use of unit values. This presents serious theoretical and practical problems when applied to "products" which are more difficult to differentiate than agricultural equipment.

### Other Approaches

The Science and Technology Statistics Division of Statistics Canada publishes statistics on trade in commodities grouped by various levels of technology. The selection of the particular commodities listed in **Canadian Science Indicators, 1983** involved a series of **a priori** judgements about the level of technology embodied in each commodity by officers of the Ministry of State for Science and Technology. This list is reproduced in Appendix I.

The External Trade Division of Statistics Canada also prepares an annual summary of imports and exports of "high technology" commodities. The list of commodities includes 19 aggregated categories; no data are provided at the sub-category level. This list was selected by various clients of the Division who receive the report. It is reproduced in Appendix I.

To summarize the foregoing, we have the following bases for defining commodities as "high technology":

- R&D content
- patents correlated with market shares
- unit values and customer opinions
- **a priori** judgements.

The resulting lists differ not only because of the various theoretical or practical grounds used for selection but also because of the different levels of aggregation used, different sources and different methods of data collection. These concerns will be illuminated in Chapter 3.

### Classification Problems

Various approaches to classifying and defining commodities as "high technology" have just been surveyed. On the level of both theory and statistical practice a number of problems arise in this area.

First, there is the problem of whether to define a commodity as "high technology" on the basis of its intrinsic function and make-up, or on the basis of the level of technology of the equipment or process used in its manufacture, or both. For example, potassic fertilizer is not an intrinsically complex commodity. Specifications for its chemical content are the same whether it is made by the most primitive or the most advanced technology. If the fertilizer was made by using advanced methods is it therefore "high technology"? This problem, along with others will be covered in a paper by the

(6) Rothwell, R., "Non-Price Factors in the Export Competitiveness of Agricultural Engineering Products", OECD, Paris, 1980.

OECD Secretariat entitled "Technological Indicators and Measurement of Performances in International Trade: Part B: Data and Empirical Tests". The whole question of the meaning of the technological content of a commodity should be answered in this paper.(7)

A second problem concerns the difficulty of disentangling "high technology" components from "low" or "medium technology" products. For example, when a manually controlled drill press or router is equipped with a numerical-control system, the question arises as to whether the entire combined unit is now "high technology" or is only the numerical-control system? Similar problems arise with any number of equipment items.

A similar problem, essentially the problem of disaggregation, occurs when it is necessary to isolate particular commodities which are "high technology" from larger commodity groupings which include commodities with a lower technology content.

The OECD Secretariat's forthcoming paper addresses another problem; namely the statistical distinction between consumer goods commodities and investment goods commodities. This will influence "high technology" balance of trade data significantly. While the distinction is in a practical sense clear-cut in most cases, the impact of importing "high technology" capital equipment is to upgrade the industrial plant of an economy, whereas the import of consumer goods is neutral in this sense. Accordingly, it is felt that it would be useful to make the distinction explicit in the indicator data.

Finally, an analysis-related problem concerns timing, i.e., leads and lags. It may well be that heavy R&D expenditures and patent activity occur long before there is a major improvement in technology resulting in improvements to competitiveness. Hence, these two indicators could be at a high level prior to the technology improvement and at a low level when the technology had in fact advanced. Apparently, the Canadian steel industry fits this scenario at the moment.

To conclude this section, it is noted that unlike many of the other science and technology indicators, trade in commodities ranked by technology enjoys a relatively high level of international comparability. According to M. Aho, a prominent analyst in the field,(8) the Standard Industrial Trade Classification, used at the 5-digit level of aggregation (maximum detail), allows for excellent international comparisons of exports and imports of "high technology" commodities. That does not mean that there are not statistical problems. For example, one cannot distinguish between computers and typewriters at this level, but no finer breakdown (6-digit) is available nor statistically feasible. In any case, qualitative changes in commodities and shifting categorization probably constitute an irreducible minimum of error which would offset any apparent increase in accuracy of a 6-digit breakdown.

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(7) Editor's note: The Industry Committee and the Committee for Scientific and Technological Policy are reviewing trade in "high technology" products and it seems likely that they will find the notion of classifying products on the basis of technology is impractical.

(8) Aho, C. Michael, U.S. Department of Labour.

## Chapter 3

### EXISTING STATISTICS

Agencies producing statistics which are relevant to this indicator include Statistics Canada, the Organization for Economic Co-operation and Development and the United States National Science Board. A summary of the published statistics and subsequent analysis is provided for each agency.

#### Statistics Canada

##### External Trade Division

The External Trade Division's data originates from two forms: the "B13 Canada Customs Export Declaration" and the "Canada Customs Import Entry Coding Form". The import form requires the importer to enter the applicable commodity code himself. The export form calls for a sufficiently detailed description of the goods to allow the customs authority to assign an appropriate code.

The External Trade Division assembles this information into individual and group codes and publishes it monthly in **Exports by Commodities** and **Imports by Commodities** (Catalogue No. 65-004 and Catalogue No. 65-007, respectively).

The list of commodity categories selected by the Division as embodying high technology is reproduced in Appendix I. Imports and exports of these commodities, labelled "Higher Technology Manufactures" are reported quarterly under the title "Impact of Technology on Canadian International Trade".

##### Science and Technology Statistics Division (STSD)

The STSD publishes an annual review (**Science and Technology Indicators**, Catalogue No. 88-201) which includes an analysis of trade data in "high technology" commodities. The source of the data used in 1983 were publications of the External Trade Division and the Department of Industry, Trade and Commerce.

The analysis of this indicator began by examining the total trade balance by commodity group: Agricultural products, Natural resources and raw materials, Energy products and Manufactured products. The balance for the first three groups is historically positive and for the last (Manufactured products), historically negative.

The Manufactured products group, in turn was broken down into High, Medium and Low technology commodities, Resource-related commodities and Motor vehicles and parts. Since 1973, the historical picture has been quite consistent, showing a positive balance for Resource-related commodities and negative balances for High, Medium and Low technology commodities, and Motor vehicles and parts (ranked here according to the size of this negative balance). A further breakdown of the "high technology" commodities group (see Chart 2 and Table 2) showed the Machinery category to be the largest single contributor to the negative balance, followed by Electrical products, Scientific instruments and other.

Chart 2

## External Trade in High Technology Commodities

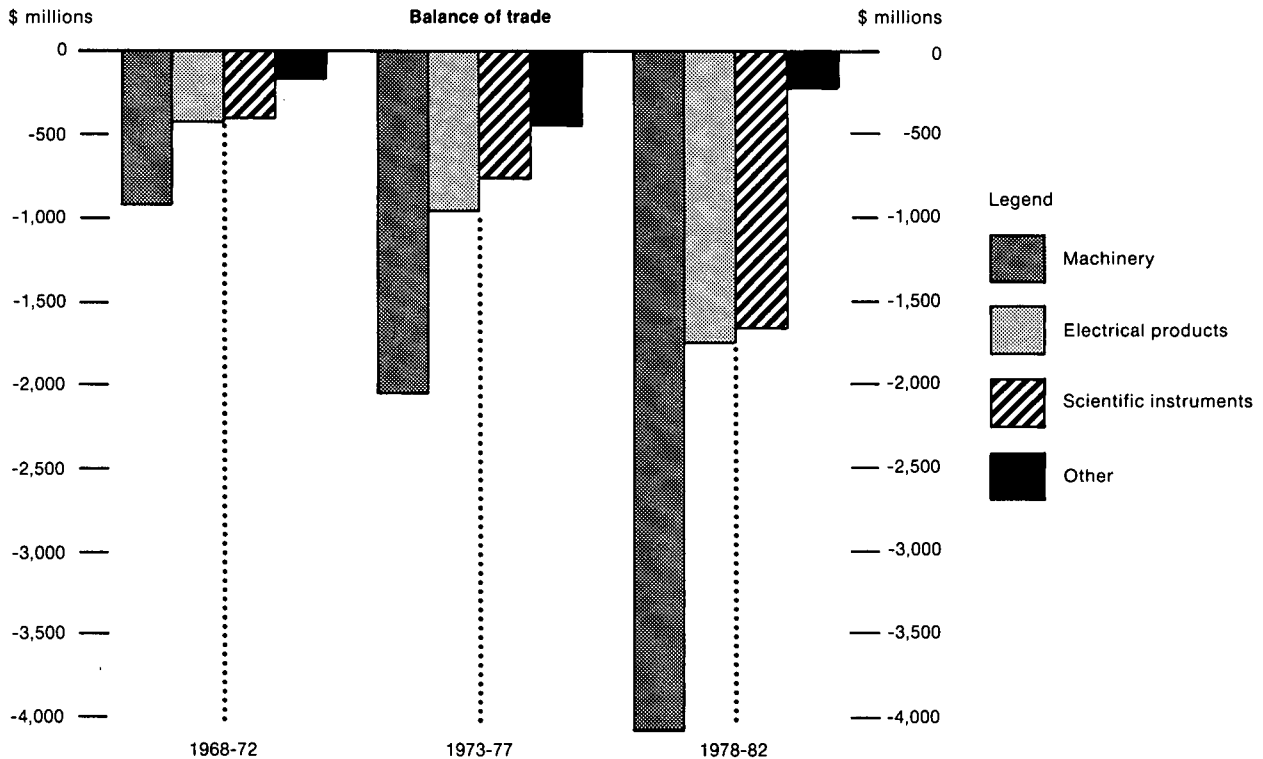


TABLE 2

## Balance of Trade in High Technology Commodities, by Commodity

Year	Chemicals	Office machinery	Other machinery	Aircraft and parts	Electrical products	Scientific instruments	Total(1)
millions of dollars							
1968 .....	-160	-150	-607	-68	-257	-332	-1,500
1969 .....	-189	-197	-672	-69	-375	-392	-1,816
1970 .....	-232	-200	-597	-4	-325	-397	-1,690
1971 .....	-192	-220	-715	43	-455	-428	-1,933
1972 .....	-230	-263	-914	181	-660	-483	-2,345
1973 .....	-254	-292	-1,096	-97	-777	-584	-3,072
1974 .....	-465	-391	-1,409	-234	-899	-722	-4,094
1975 .....	-364	-386	-1,803	-274	-833	-773	-4,410
1976 .....	-283	-404	-2,067	48	-1,097	-804	-4,591
1977 .....	-360	-451	-1,973	47	-1,311	-1,025	-5,061
1978 .....	-85	-600	-2,267	-149	-1,523	-1,240	-5,835
1979 .....	9	-706	-3,054	-359	-1,747	-1,455	-7,292
1980 .....	223	-1,164	-3,333	-425	-1,726	-1,732	-8,132
1981 .....	233	-1,708	-3,374	-850	-2,018	-1,988	-9,705
1982 .....	113	-1,937	-2,325	227	-1,811	-1,910	-7,643

(1) Includes ordnance.

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue No. 88-201, 1983, Figure 9.3 and Table 61.

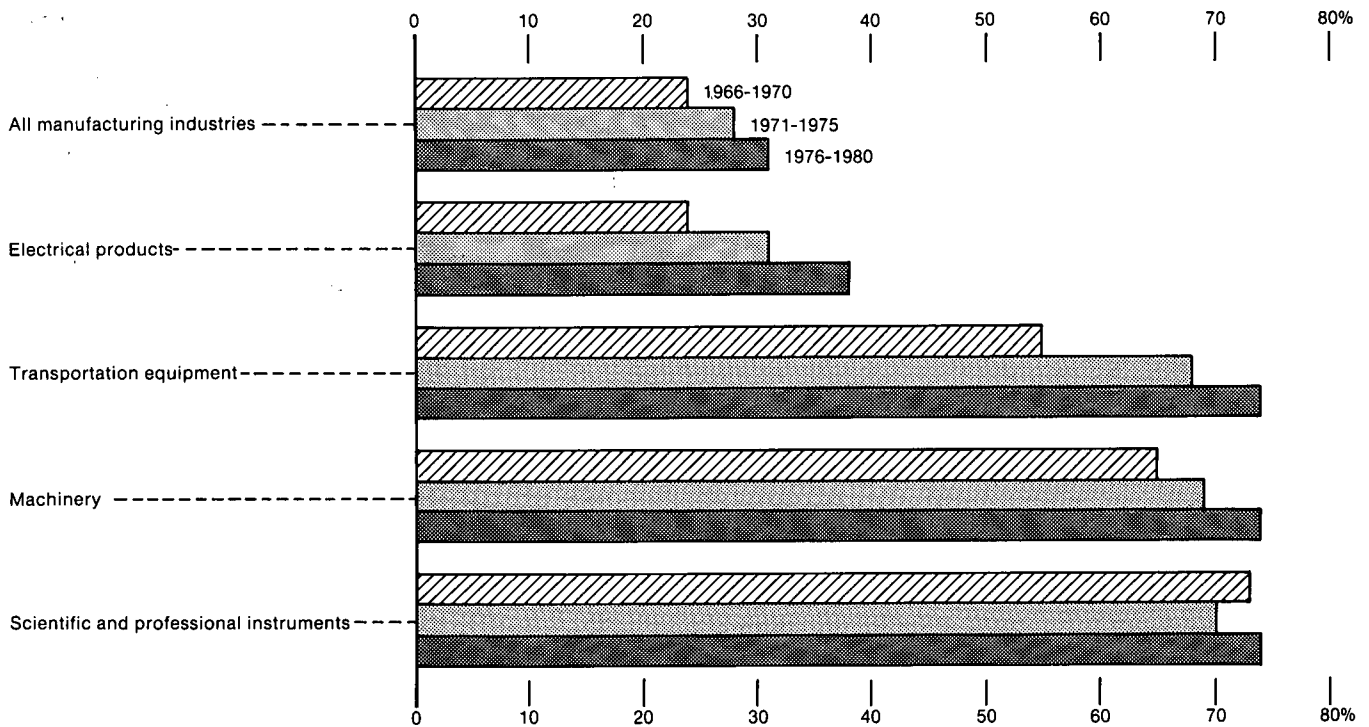
Further analysis was based on data published by the Department of Industry, Trade and Commerce, Economic Intelligence Branch as "Manufacturing Trade and Measures".

"Import penetration" provides insight into the extent of our imports of "high technology" commodities - the statistic represents imports as a percentage of the Canadian market for each commodity group. For all manufacturing industries the figure for the period 1976-1980 is of the order of 30% (see Chart 3 and Table 3). Three "high technology" commodity groups within that figure show an import penetration in excess of 70%, namely Transportation Equipment, Machinery, and Scientific and Professional Instruments. The Electrical Products figure is close to 40%. More detailed product breakdowns are provided in the supporting tables at the back of the publication.

Similar data are provided by the Economic Intelligence Branch on the export orientation of selected manufacturing industries. The figure for export orientation is that percentage of each industry group's total shipments which is exported.

Chart 3

## Import Penetration, Selected Manufacturing Industries



**TABLE 3**  
**Import Penetration(1) of Selected Manufacturing Industries**

Industry	1966	1968	1970	1972	1974	1976	1978	1980	1981
per cent									
Rubber and plastic products .....	14	16	17	20	27	21	22	22	22
Metal fabricating .....	12	12	13	14	15	15	16	15	15
Office machinery .....	63	70	82	86	82	90	94	96	95
Other machinery .....	64	63	63	65	69	69	71	72	73
Aircraft and parts .....	40	56	67	96	76	56	67	67	66
Other transportation equipment .....	39	59	67	68	67	71	77	72	73
Communication equipment .....	33	29	32	40	40	39	47	56	59
Other electrical products .....	18	21	23	27	30	33	37	34	35
Drugs and medicines .....	15	14	17	17	20	20	13	17	15
Other chemical products .....	24	25	28	29	32	30	36	34	33
Scientific and professional equipment .....	84	80	90	77	80	76	82	79	81
<b>All manufacturing - Total .....</b>	<b>21</b>	<b>24</b>	<b>26</b>	<b>28</b>	<b>29</b>	<b>29</b>	<b>32</b>	<b>32</b>	<b>32</b>

(1) Import penetration = Imports ÷ Canadian market.

Canadian market = Shipments from Canadian establishments - exports + imports.

**Source:** Canadian Science Indicators, 1983, Statistics Canada, Catalogue No. 88-201, 1983, Figure 9.4 and Table 63.

## Organization for Economic Co-operation and Development

### Directorate for Science, Technology and Industry

The most recent paper on the subject of trade in "high technology" commodities was released by the Organization for Economic Co-operation and Development (OECD) on April 8, 1983, and is entitled "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach". In September 1983, the OECD held a seminar on trends in technology and a number of papers should be available from this workshop in the near future.

The list of commodity groupings on which the April study is based is reproduced in Appendix I.

The study carries out extensive analysis using the trade and output data of this list as the basis for the following tables:

- Market Shares, by Country
- Export-Import Ratios of OECD member nations
- Interbranch Specialization, by Country
- Coefficient of Dependence on Imports, by Country
- Demand-elasticity of Exports of High Technology Products, by Country
- Domestic Demand-elasticity of Imports, by Country.

Here we will present the main thrust of the analysis, which hinges on measures of international specialization, and on the market strategies of the governments and the multinational corporations in terms of the use of alternative routes for the transfer of technology.

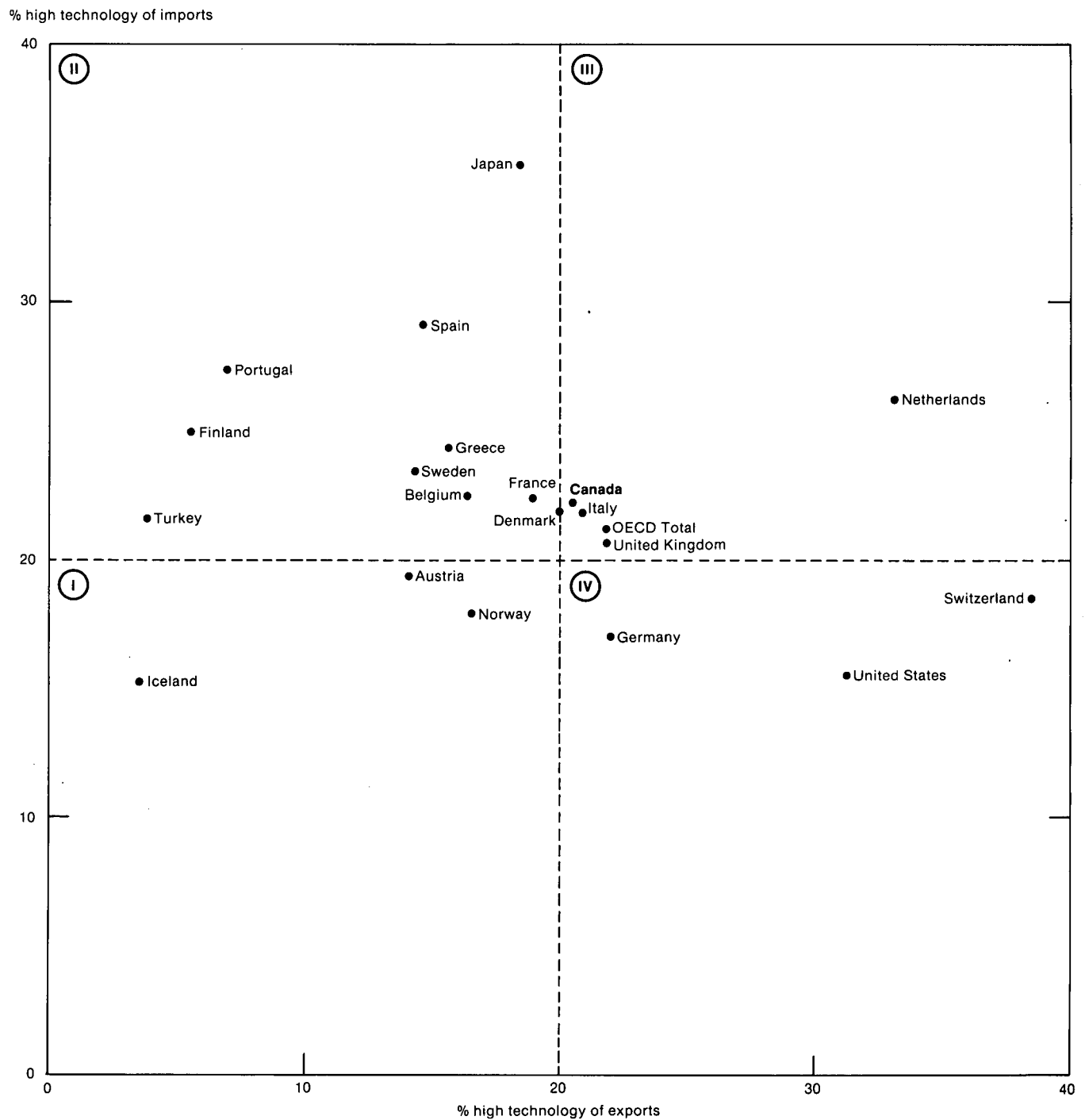
The central measure of specialization elaborated upon in the subject paper is to take "high technology" products as a percentage of imports and exports of all manufactures. Charts 4 and 5 are based on this data and show the relative positions of the OECD member countries in 1963 and in 1980, respectively.

From the point of view of a country wishing to reach a position of technological leadership, it is probably most desirable to be in Quadrant IV with a high proportion of "high technology" commodities (which are generally of high value) in its exports and a low proportion in its imports. The "hewers of wood and drawers of water" and the less developed countries would find themselves in Quadrant II, importing "high technology" and exporting "low technology" commodities.

The two charts compare 1963 with 1980 and show that the most advanced countries have generally increased the "high technology" component of their imports while maintaining or improving their "high technology" specialization in exports. In Canada's case the export specialization was basically maintained, while the proportion of "high technology" imports went up.

Chart 4

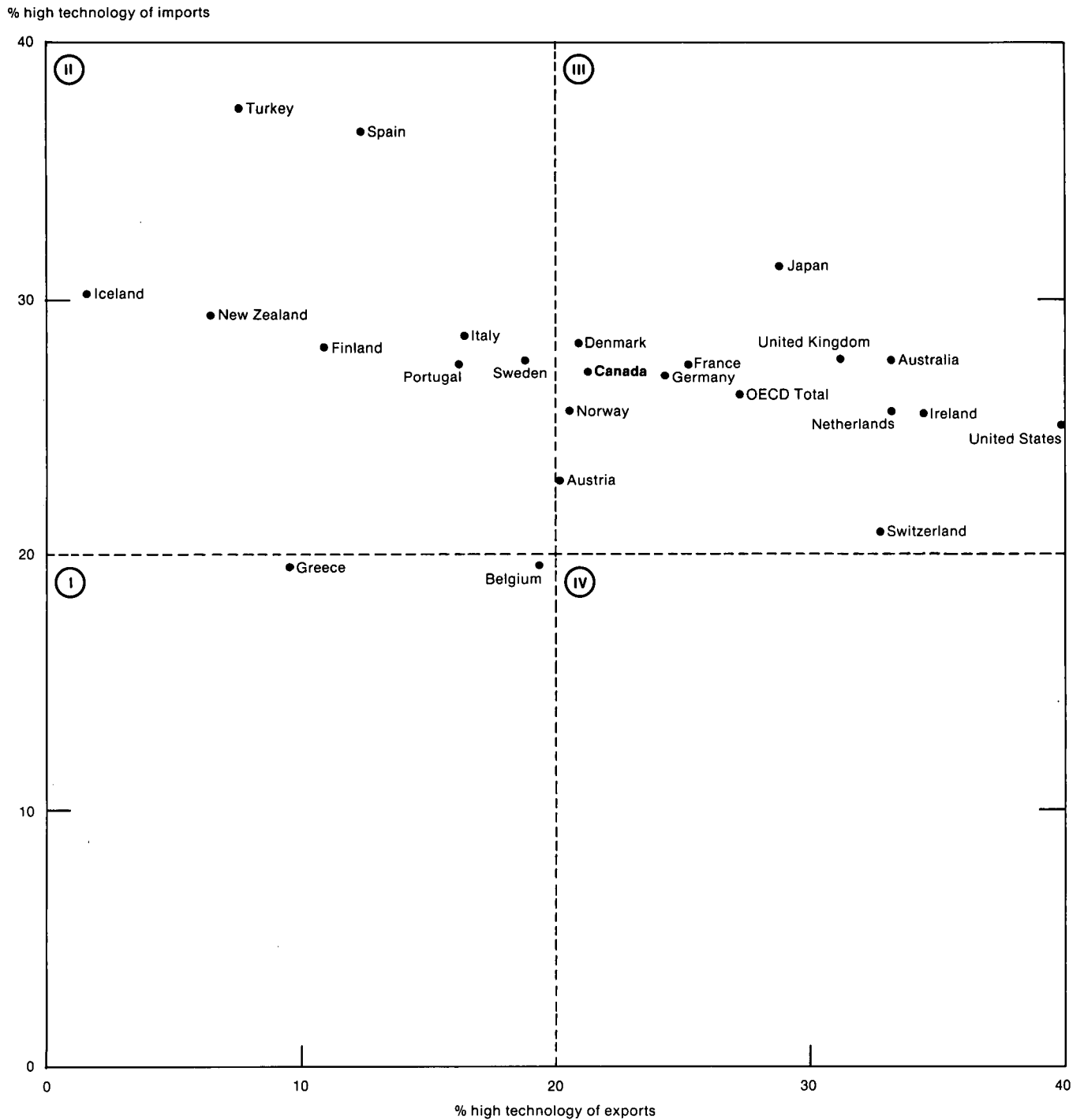
# Shares of High-technology Products in the Exports and Imports of Manufactured Products in 1963



Source: "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", OECD, DSTI/SPR/83.13, 1983, Graph 1.



Chart 5  
**Shares of High-technology Products in the Exports and Imports of Manufactured Products in 1980**



Source: "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", OECD, DSTI/SPR/83.13, 1983, Graph 2.

The OECD also produced an index of "interbranch specialization", i.e., specialization in "high technology" commodities for each country, which it then related to overall market shares. This resulted in the following figures for 1963-1971 (see Chart 6) and 1971-1980 (see Chart 7).

The following is the OECD's analysis of the graphs:

"This link between market shares and the degree of specialisation is well illustrated by Graphs 3 (Chart 6) and 4 (Chart 7). During the two periods considered, the United States, which holds about one-quarter of the world market, is still the country specialising the most in advanced technology (more than 150 points), although in real terms it loses about 1.5% of the world market. Germany, with much less specialisation, manages to win one-fifth of the world market and regresses slightly (-2%) over both periods. The United Kingdom is the only large country which is losing 4% of the market, and during the second period it is overtaken by Japan which becomes the third largest exporter in the world. France, just behind the United Kingdom (fifth largest exporter in the world) has the same degree of specialisation as Germany but its markets are only half as large as Germany's. The two most specialised countries coming immediately after the United States are the Netherlands (sixth largest exporter in the world) and Switzerland, but these two hold less than 5% of the world market. Australia and Ireland, with less than 1% of the world market, have approximately the same degree of specialisation.

"Another group of countries consists of Canada, Austria, Belgium, Sweden, Italy, Portugal and Norway, which are quite specialised, but only Italy, Belgium, Canada and Sweden have significant market shares. The last group of countries is made up of Spain, Greece, Finland, Turkey and New Zealand, whose main feature is the very small degree of specialisation and the very small market shares resulting from this."(9)

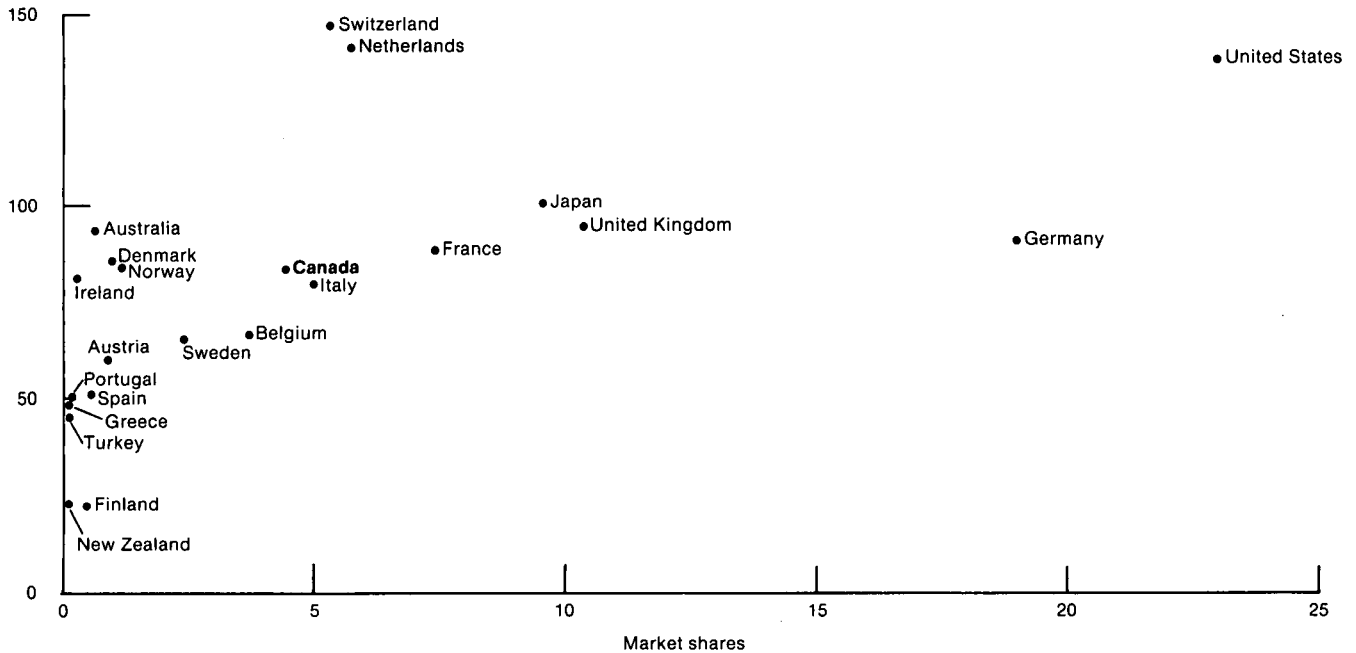
[The conclusions of the Secretariat's note are reproduced in full in Appendix II to demonstrate the sort of analysis that is possible on the basis of the data produced by the OECD.]

(9) "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", op. cit., p. 74.

Chart 6

**Specialisation and Market Shares (average 1963-71)**

Interbranch specialisation

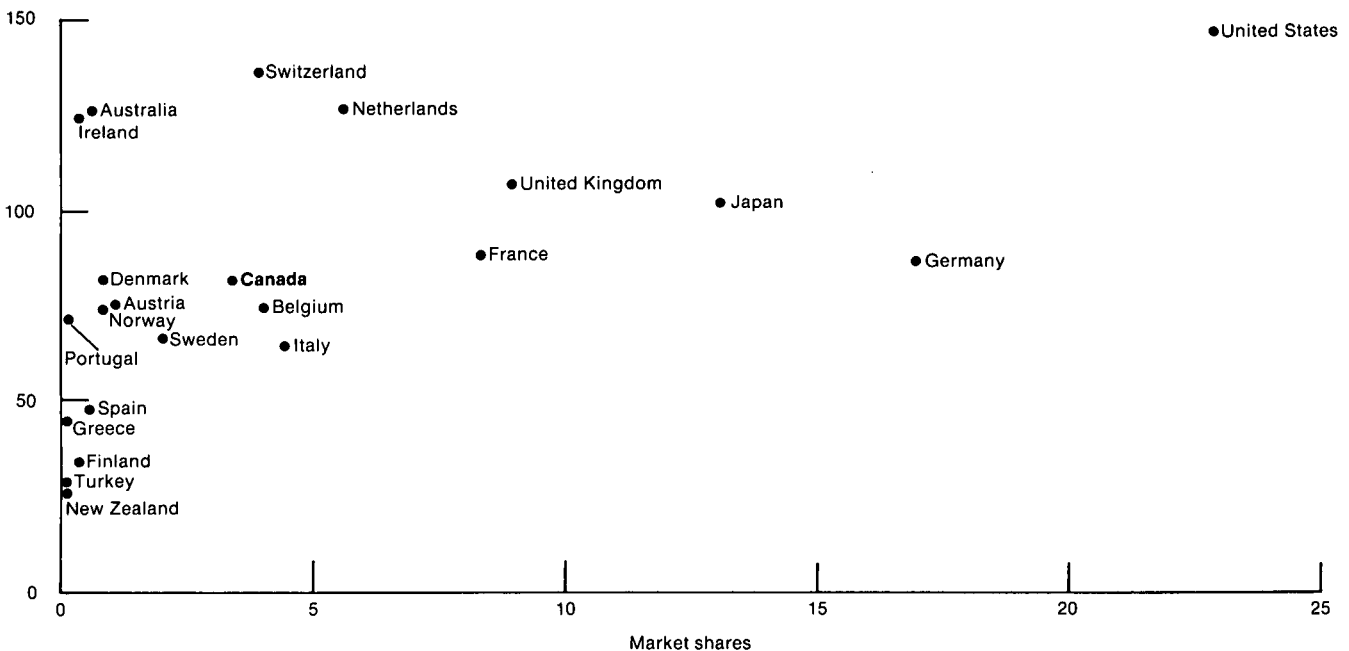


Source: "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", OECD, DSTI/SPR/83.13, 1983, Graph 3.

Chart 7

**Specialisation and Market Shares (average 1971-80)**

Interbranch specialisation



Source: "Experimental Studies on the Analysis of Output Part 2: International Trade in High Technology Products: An Empirical Approach", OECD, DSTI/SPR/83.13, 1983, Graph 4.

## National Science Board

In the National Science Board's biennial publication **Science Indicators**, foreign trade in "R&D-Intensive" manufactured products is analyzed using data from the U.S. Department of Commerce and the Department of Labour.

The analysis in the 1980 report began with Chart 8A showing the U.S. trade balance in R&D-intensive manufactured products in juxtaposition with the balance in non-R&D-intensive manufactured products.

This is followed by a breakdown of the aggregate R&D-intensive balance into four component commodity groupings as shown in Chart 8B.

The remainder of the analysis concerns international comparisons - first the trade balance with selected nations, including Canada, and second some comparative trend data on the leading countries' market shares in the combined markets of the developed countries, the less developed countries and the world as in Charts 9A and 9B.

Chart 8A

### U.S. Trade Balance<sup>(1)</sup> in R&D-intensive and non-R&D-intensive Manufactured Product Groups

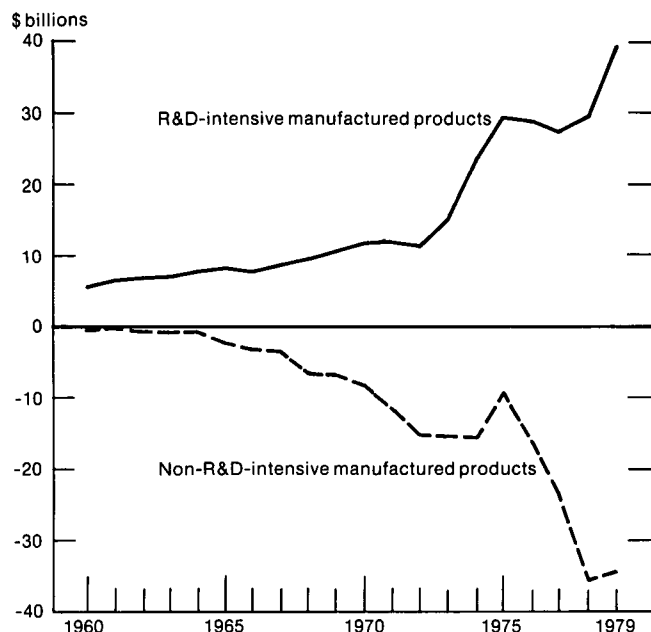
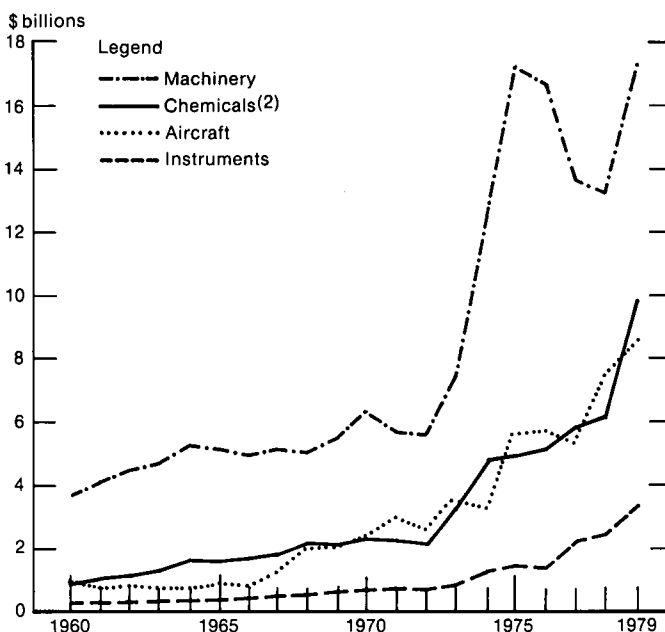


Chart 8B

### U.S. Trade Balance<sup>(1)</sup> in Selected Product Groups



(1) Exports less imports.

(2) Includes drugs and other allied products.

NOTE: After 1977, the Commerce Department made revisions in the product group classifications which somewhat affected the balance of these product groups. The overall R&D-intensive balance was unaffected.

Source: Science Indicators — 1980, National Science Board, Washington, D.C., Figures 1-12, 1-13.

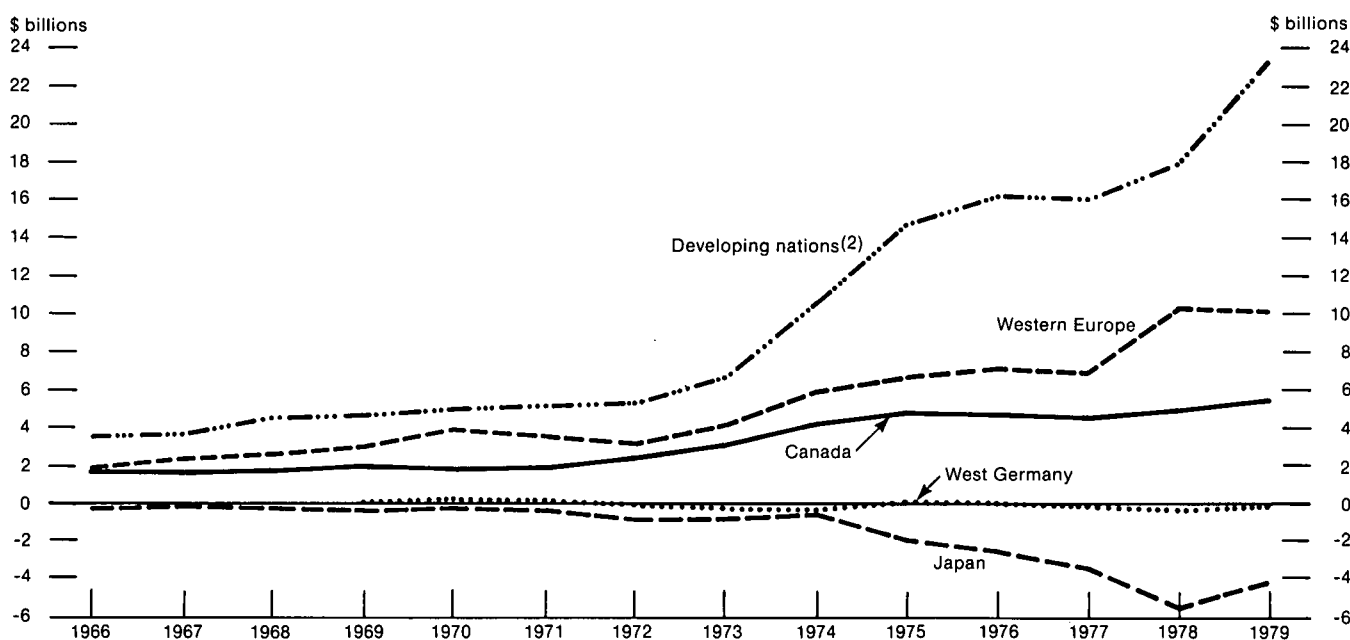
**CHART 9A****Export Market Shares for R&D-intensive Goods in Developed and Developing Countries**

	1962	1970	1977
<b>United States</b>			
DC(1) .....	20	22	17
LDC(2) .....	46	31	24
World .....	28	23	19
World w/o autos .....	31	27	21
<b>Japan</b>			
DC .....	3	8	14
LDC .....	6	15	22
World .....	4	10	16
World w/o autos .....	3	10	14
<b>France</b>			
DC .....	8	8	9
LDC .....	7	9	9
World .....	8	8	10
World w/o autos .....	7	7	8
<b>Germany</b>			
DC .....	26	21	22
LDC .....	11	12	14
World .....	21	19	20
World w/o autos .....	17	17	18
<b>United Kingdom</b>			
DC .....	17	9	7
LDC .....	15	12	9
World .....	17	10	8
World w/o autos .....	14	10	9

(1) DC - Developed countries.

(2) LDC - Less developed countries.

Source: Science Indicators - 1980, National Science Board, Washington D.C., 1981, Table 1-11.

**Chart 9B****U.S. Trade Balance<sup>(1)</sup> with Selected Nations for R&D-intensive Manufactured Products**

(1) Exports less imports.

(2) Includes the Republic of South Africa in 1966 and 1967.

Source: Science Indicators - 1980, National Science Board, Washington, D.C., 1981, Figure 1-14.



## Chapter 4

### SUMMARY

There is no question that commodity statistics are important indicators of a country's technological advancement and its competitiveness. They are necessary background information for government policy makers, economists, bankers, and members of the World Bank Organization, the International Monetary Fund (IMF) and similar agencies.

While changes in international practices have probably reduced the importance of this single facet of technological measurement, freer trade, changes in industrial structure, or changes in governments' policies might very well bring it to the forefront again as a stronger indicator. Meanwhile, analyses such as those of Statistics Canada, the National Science Foundation and the OECD, provide both macro and micro views of trends that are of crucial interest to those who make government policies on trade regulations, tariffs and incentives to industry. The data concern one of the most volatile segments of our international trade and our domestic economy and comprise dollar totals of the order of \$30 billion per year. Anything that a government can do to improve a nation's balance of trade in "high technology" products will profoundly affect that nation's basic wealth, standard of living and general progress. Knowledge of the trends of that trade overall and in its components is an essential pre-condition for intelligent action.





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## Appendix I

### LISTS OF "HIGH TECHNOLOGY" COMMODITIES

#### Science and Technology Statistics Division, Statistics Canada

High Technology Commodities: Imports (1983 List)

##### Chemicals:

- Inorganic chemicals
- Synthetic and reclaimed rubber
- Plastics materials, not shaped
- Plastic film and sheet
- Other plastics, basic shapes and forms
- Medicinal and pharmaceutical products

##### Machinery:

- Engines and turbines, diesel, general purpose (g.p.)
- Engines and turbines, g.p., not elsewhere stated (n.e.s.)
- Electric generators and motors
- Compressors, blowers and vacuum pumps
- Pumps, except oil well pumps
- Other g.p. industrial machinery
- Drilling machinery and drill bits
- Power shovels
- Bulldozing and similar equipment
- Front end loaders
- Other excavating machinery
- Mining, oil and gas machinery
- Construction and maintenance machinery
- Pulp and paper industries machinery
- Agricultural machinery and tractors

##### Aircraft:

- Aircraft, complete with engines
- Aircraft engines and parts
- Aircraft parts, except engines

##### Electrical products:

- Telephone and telegraph equipment
- Televisions, radios and phonographs
- Electronic tubes and semi-conductors
- Other telecommunications equipment
- Switchgear and protective equipment
- Industrial control equipment
- Other electric lighting dist. equipment
- Auxiliary electric equipment for engines

##### Scientific instruments:

- Electrical property measuring inst.
- Misc. measuring, controlling instr.
- Medical and related equipment
- Navigation equipment
- Other measuring, lab equipment
- Medical ophthalmic, ortho. supplies
- Unexposed photographic film and plates
- Other photographic goods

**External Trade Division, Statistics Canada**

Higher Technology Manufactures (imports and exports)

Man-made fibres

Chemicals

Petroleum and coal products

Industrial machinery

Mechanical handling equipment

Other industrial machinery

Agricultural machinery

Railway locomotives and rolling stock

Road transport equipment

Aircraft and parts

Other vehicles

Communications equipment

Heating, refrigeration and air conditioning equipment

Miscellaneous domestic and commercial appliances

Measuring and control equipment

Tools

Office machinery

Medical and pharmaceutical supplies

Photographic goods and equipment

## Organization for Economic Co-operation and Development

(Based on U.S. Department of Commerce classification approach)

### Aircraft and parts:

- Aircraft engines [including jet engines]
- Aircraft hulls

### Office computing and accounting machines:

- Office machines
- Computing and accounting machines

### Electrical transmission and distribution equipment:

- Electrical apparatus for electrical circuits
- Electrical measuring and controlling apparatus
- Electric power machinery
- Electrical machinery and apparatus

### Communications equipment and electronic components:

- Telecommunications equipment
- Electronic valves and tubes, transistors
- Electron and proton accelerators
- Gramophone records and other recording media

### Professional and scientific instruments:

- Pharmaceutical goods
- Scientific measuring and controlling instruments
- Photographic and cinematographic supplies
- Clocks and watches

### Drugs:

- Medicinal and pharmaceutical products
- Pharmaceutical goods

### Plastic materials and synthetics:

- Synthetic rubber and rubber substitutes
- Synthetic and regenerated (artificial) fibres
- Plastic materials, regenerated cellulose and artificial resins
- Regenerated cellulose and vulcanised fibre

### Engines and turbines:

- Steam engines and turbines
- Internal combustion engines other than for aircraft
- Gas turbines other than for aircraft
- Water turbines and other water engines

### Agricultural chemicals:

- Manufactured fertilizers
- Potassic fertilizers
- Insecticides, fungicides, disinfectants

### Industrial inorganic chemicals:

- inorganic chemicals: elements, oxides and halogen salts
- other inorganic chemicals
- radioactive and associated materials
- colouring materials
- potassic fertilizers

### Radio and television receiving equipment:

- television broadcast receivers
- radio broadcast receivers
- gramophones, tape recorders and other sound recorders





## Appendix II

EXCERPT FROM "EXPERIMENTAL STUDIES ON THE ANALYSIS OF OUTPUT PART 2: INTERNATIONAL TRADE IN HIGH TECHNOLOGY PRODUCTS: AN EMPIRICAL APPROACH", NOTE BY THE SECRETARIAT, OECD, DSTI/SPR/83.13, PARIS, 1983.

"We have just seen that high-technology products make up an important growth factor for the whole of the OECD area.

"The greatest growth in high-technology products has been recorded by Japan, France, the United Kingdom, the United States, Germany, Belgium and Sweden. Italy, the Netherlands, Canada and Switzerland, on the other hand, have experienced a more rapid rise in their exports of low-technology products than in those of high-technology products.

"The performance of Japan is all the more important since it is the only OECD country which has achieved simultaneously a very large rise in the share of high-technology products in its exports and a sharp decline in those products in its imports.

"We have also seen that in general, the spread of technical progress has had a two-fold consequence. First, it has contributed to the expansion of exports of all OECD countries, but at the same time it has made possible greater specialisation, which has increased the interdependence between the Member countries.

"This increase in specialisation, combined with an increase in risks in investment and trade, will in the years to come increasingly encourage links and co-operation agreements between firms in different countries, when their technological and trade advantages are complementary.

"... there are four main factors explaining international trade: world demand, factor endowment, technology and economies of scale. The demand factor would seem to be the most important of these. The fall in world exports over the last two years (1981 and 1982) cannot basically be imputed to any other factors.

"The fall in world demand probably explains not only the decline in exports but also the fallback in direct investment and probably in technological exchanges.

"We have seen, however, that this fall does not apply to all products. The question therefore arises of whether the structure of international specialisation is suited to that of world demand.

"The strength of Japanese exports probably lies in a good balance between specialisation and demand. Despite the worldwide stagnation of trade, exports of those products in which Japan is specialised have hardly declined at all. The elasticity of these products in relation to world demand has been twice as high for Japan as for its main competitors.

"Demand is probably not, however, a sufficient explanation of the loss of competitiveness of Europe and the United States for certain products, such as those connected with consumer electronics. For most of these very technology-intensive products, the role of technology is as important as demand. We have seen that the fall in R&D over the earlier period in Europe and the United States was a fairly good explanation of the high penetration of Japanese products in these markets.

"The oligopolistic advantage enjoyed hitherto by Japan, however, at least for certain products in the radio-television equipment group, will be considerably reduced by the limitations imposed on its exports and the restructuring of production on the European market. Already the Japanese manufacturers have begun to step up the output of their European and American subsidiaries.

"Factor endowment can also provide a very good explanation of the relative advantage of certain countries for certain products. Natural resources have often been referred to in the case of inorganic chemicals and agricultural chemicals. Human capital has been pointed out as a production factor, especially for Japan and the United States. We have also analysed on several occasions the role of physical capital as a factor in exports.

"Finally, we have found that the role of economies of scale is still important in the case of specialisation in the small countries. We have seen that the small countries specialise either in fairly standardised lines of goods which ensure economies of scale, or in lines that are less standardised, but this at the cost of a considerable effort of specialisation and concentration of financial resources.

"Throughout this study we have been mainly dealing with facts but have at the same time tried to show what are the factors which in our view have some claim to be causal. The whole question of the causality of these factors has still, however, to be analysed, and the assumptions must be tested rigorously by statistics.

"The methodology of identifying the technology-intensive products will have to be re-examined and widened. The role of technology in trade should be redefined in the light of the three strategies for winning markets: exports, direct investment and transfers of technology. Technology intervenes, however, first of its own accord in the trade in licenses, patents and know-how, but also as an explanatory factor in exports and in the benefits connected with direct investment. In exports of comparatively straight forward products, technology plays an indirect part as a production factor in the same way as capital, labour, energy and raw materials. In the case of exports of high-technology products, however, it constitutes, with demand, the decisive explanatory factor."

## PROPOSED PUBLICATIONS ON SCIENCE AND TECHNOLOGY INDICATORS

### Catalogue

- 88-501E An Indicator of Excellence in Canadian Science
- 88-502E International Payments and Receipts for Technology
- 88-504E Patents as Indicators of Invention
- 88-505E Industrial Productivity and Research and Development Indicators
- 88-506E A Framework for Measuring Research and Development Expenditures in Canada  
(published March 1984)
- 88-507E An Indicator of Excellence in Canadian Science: Summary Report  
(published May 1984)
- 88-508E Human Resources for Science and Technology in Canada

These publications are also available in French.

Statistical reports for most indicator series are being developed for annual publication by Statistics Canada. Existing publications are listed below.

## STATISTICAL PUBLICATIONS

### Catalogue

- 88-001 Science Statistics, Monthly
- 88-201 Science and Technology Indicators, Annual
- 88-202 Industrial Research and Development Statistics, Annual
- 88-203 Resources for Research and Development in Canada, Annual
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