THE CANADIAN ELECTRONICS INDUSTRY: INNOVATION, RATIONALIZATION AND PUBLIC POLICY

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Abstract

In recent years the rapid growth in the demand for electronic products and technology has led many countries to designate the electronics industry as a strategic sector. Motivated by a perception that a presence in electronics is somehow crucial to future industrial performance, governments of producer countries have frequently intervened in the market to support domestic manufacturers through protection and the provision of large R&D subsidies. Despite the popularity of these measures there has been little in the way of economic analysis to support the degree of intervention which has taken place. This study attempts to provide a much needed economic analysis of issues which concern appropriate public policy for the Canadian electronics industry, with particular emphasis on trade and R&D.

Extrait

Ces dernières années, la croissance rapide de la demande pour les produits et la technologie électroniques a amené plusieurs pays à désigner l'industrie de l'électronique comme étant un secteur stratégique. Motivés par l'intuition qu'une présence dans l'électronique est en quelque sorte décisive au rendement industriel futur, les gouvernements des pays producteurs sont fréquemment intervenus dans le marché pour supporter les manufacturiers locaux en adoptant une politique protectioniste et en accordant de larges subventions pour la recherche et le développement. En dépit de la popularité de ces mesures, il y a eu peu d'analyses économiques entreprises pour supporter le degré d'intervention qui avait lieu. Cette étude tente de fournir une analyse économique si nécessaire des issues concernaut une politique gouvernementale appropriée pour l'industrie de l'électronique, en accentuant l'aspect commercial et le domaine de la recherche et du développement.

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INTRODUCTION

The recent growth in the domestic production of electronic components and end-products has drawn attention to the rapid evolution of high technology industries in Canadian manufacturing. Many anticipate that these industries will become increasingly important in the future and should therefore be given special support. Proponents of intervention point to the extent to which other countries have supported their industries, notably through public procurement and R&D subsidies. They argue that the Canadian government must provide its electronics industry with comparable support if domestic producers are to compete effectively in international markets.

Can such interventionist policies be justified on economic grounds? In addressing this question the following study provides an analysis of the electronics industry's development over the last decade and evaluates policy options within the context of achieving the greatest net social benefits for Canada. It is argued that the adoption of policies which call for extensive intervention in the industry is unlikely to produce significant benefits for Canada. This is particularly evident in the area of trade policy, where the size of the domestic market in relation to minimum efficient scale emphasizes the urgent need for trade liberalization. Nevertheless, there may be scope for some intervention in the form of public subsidies, loans and/or equity investments to ensure that firms allocate the socially optimal level of resources to R&D.

Chapter 1 sketches the major features of the industry's recent structure and performance, noting a number of trends which suggest increasing rationalization. Chapter 2 pursues the theme of rationalization by providing case studies of structural adjustments in two industry sub-sectors and examines the influence of trade and government policy on specialisation. Chapter 3 deals with the design of appropriate trade policy. A principle concern is whether considerations for scale efficiency indicate a need for sectoral trade liberalization. This entails an assessment of the applicability of infant industry protection to the various sub-sectors of the electronics industry. The scope and effectiveness of R&D policy is addressed in Chapter 4. The analysis suggests a rationale for intervention based on externalities and risk bearing. However, it raises questions concerning the effectiveness of subsidy programs in light of the results obtained from an empirical investigation into the determinants of R&D spending by electronics firms.

CHAPTER 1

THE STRUCTURE AND PERFORMANCE OF THE CANADIAN ELECTRONICS INDUSTRY

Technical Background

Electronics covers a wide array of products and processes which involve a controlled flow of electrons passing through a specific medium or vacuum. Within the context of this broad definition there are two separate categories of electronic goods, one based on digital circuitry and the other an analogue circuitry.

Analogue circuits are found where wave signals require amplification as is the case in radios, televisions, and until recently, telecommunication equipment designed for voice transmission. However, with the development of semiconductors, analogue circuits have been widely replaced by digital systems and the technology is no longer in the mainstream of modern electronics.[1]

Virtually all of the major innovations in electronics over the last three decades have involved the successive miniaturization of digital circuits. In digital electronics the flow of electrons is manipulated to produce a sequence of electronic pulses. These pulses are encoded in binary digits and thus convey digital information. For example, the presence of an electronic pulse may be denoted by a one binary digit whereas the absence of a pulse may be designated by a zero digit. Through regulating the flow of current it is possible to alternate the frequency of pulses and produce different signal sequences.

The development of digital circuitry and microelectronics is based primarily on the discovery of the semiconductor. A semiconductor is a device (made generally from silicon) which, depending on the level of voltage, can act as either an insulator or conductor of current. Originally, semiconductors were discrete components which had to be interconnected to form a complete circuit. Later developments in photolithography (the planar process) enabled complete microcircuits to be 'baked' onto the surface of small silicon wafers. The resulting integrated circuit eliminated the difficult problem of manually interconnecting separate circuit elements (i.e. transistors, rectifiers, capacitors etc.), thus permitting further miniaturization of these components.

Integrated circuits are produced from the fabrication of silicon wafers. When divided, a single wafer may contain as many as 175 separate integrated circuits. This limit is set by the purity of silicon crystals which declines as the wafer exceeds a certain maximum diameter. Once broken into individual integrated circuits, the silicon chips are enclosed in a ceramic or metal casing and then attached to small wires which connect them to an external power source[2].

Both the efficiency and capacity of an integrated circuit are a function of the dimensions of the circuit's components. Although the speed at which electrons travel is a constant, the time taken for a signal to pass through a circuit is variable depending on the area of the circuit. Smaller components reduce the distance through which the current must pass and thus shorten the time in which the signal remains in the circuit. In addition, miniaturization facilitates a greater circuit density which otherwise is limited by the maximum dimensions of a chip[3]. For these reasons, efforts to reduce the cost of electronic functions have focused on the miniaturization of components. In recent years this has led to techniques for medium and large scale integration which have resulted in integrated circuits with a capacity of 64,000 bytes (binary units). As the precision of photoengraving technology approaches optical limits, lasers and other technologies involving the use of non-visible wavelengths of light are being employed to further reduce circuit dimensions. These developments underlie the achievement of very large scale integration associated with integrated circuits with capacities of 256,000 bytes. It is believed that the introduction of these circuits will open up new frontiers for the application of electronic technology.

INDUSTRY STRUCTURE

An Overview of the Canadian Industry

The electronics industry is so diversified that it is not possible to identify it by a single product group. Consequently the industry is not contained within a single industrial classification. It is, instead, scattered across a number of SICs, principally SIC 318 (Office and Store Machinery), SIC 334 (Household Radio and Television Receivers) and SIC 335 (Communications Equipment). This coverage in itself is inadequate. Non-electronic and electronic goods are frequently lumped together and vital distinctions between different categories of electronic goods are obscured by aggregation.

An alternative approach toward the statistical delineation of the industry is to work with ICCs (Industrial Commodity Classifications). Five sub-sectors within the electronics industry have been identified on this basis; telecommunications, computers and other electronic office equipment, consumer products, components and electronic instruments and systems. There are two problems with these data that merit attention. First, they contain information primarily on trade and exchange, not on production, employment and productivity which is instead found in the SIC data. It is extremely difficult to integrate the SIC and ICC data into a common statistical framework. Therefore at times it will be necessary to refer to each one of these data sources separately. A second, and in the long-run more serious problem is that product distinctions on which the sub-sector typology is based, are rapidly becoming obsolete as technology changes. For example, telecommunications equipment and computers are no longer as sharply differentiated as they once were and will become less so in the future. Similarly, distinctions between electronic systems equipment and sub-system components are often arbitrary. In spite of these drawbacks with the existing data it is still possible to describe the industry's structure and performance. It is useful, however, before considering these features to provide an overview of the organization and composition of the Canadian electronics industry.

The composition of the industry is shown schematically on the following page. The industry consists of a components sector and a variety of electronic end-product sectors. It is often argued that because of its centrality, components are strategically positioned within the industry[4]. The linkage between components and all other branches of the industry suggests that technical change embodied in the design and composition of components affects the cost and technological characteristics of electronic end-products.

Components encompass a wide spectrum of heterogenous products ranging from discrete semiconductors and tubes to integrated circuits. The trend in recent years has been toward customized components designed to perform particular functions for specific end-products. Associated with customization, is the tendency for end-users to manufacture their own micro-electronic chips.

A Schematic View of the Electronics Industry

COMPONENTS

- discrete semiconductors
- integrated circuits
- electronic tubes

CONSUMER PRODUCTS

- televisions
- radios
- tape recorders
- stereo equipment
- microwave ovens
- electronic video games

TELECOMMUNICATIONS

- telephone equipment
- satellite transmission
- cable systems
- mobile telecoms
- fibre optics
- radio and TV broadcast equipment
- microwave transmission

COMPUTERS AND OFFICE EQUIPMENT

- mainframe computers
- microprocessors
- calculators
- mini and micro computers
- word processors
- electronic typewriters

INSTRUMENTS

- scientific measuring and control equipment
- industrial process and control equipment
- robotics

ELECTRONIC SYSTEMS

- marine, aircraft and traffic control systems
- pipeline and electric power transmission and distribution systems
- defense and aerospace systems

Component production in Canada is minor by world standards. There is no longer a major component firm in Canada[5]. However, there are a number of small firms in the sub-sector that produce highly specialized components which are sold to both domestic and foreign end-product manufacturers. Furthermore, some of Canada's major telecommunications firms manufacture their own integrated circuits and have made important technological innovations in this area[6].

Telecommunications represents one of the more important applications of electronic components. The telecommunications sub-sector is by far the most significant segment of the Canadian electronics industry and contains its largest firm, Northern Telecom. The sub-sector covers a variety of products including phone systems, satellite and microwave broadcast-transmission systems, mobile receivers, navigation equipment and defense related communication equipment. Canada is a world leader in telecommunications-technology; firms in this sector are major exporters and are among the fastest growing in the country.

Canada's strength in this area of electronics reflects a long-standing specialization in telecommunication technology and a significant increase in the electronic content of that technology. Canada's geography, marked by the distant separation of population, has compelled the country to be at the forefront of long distance communication technology. In recent years this technology has increasingly involved the application of microelectronics and a concomitant shift from analogue signals to digital ones. This has led to the replacement of electro-mechanical switching devices by specialized large scale and very large scale integrated circuits. It is also leading to the dissolution of distinctions between the telecommunications industry and the computer industry since systems designed to carry digital signals are suitable for both data and voice transmission[7].

Computers are one of the more traditional areas of electronics. Until recently, because of the cost and inflexibility of mainframe computers, their use was restricted to a relatively narrow range of data processing functions. However with the development of micro-processors the cost of most computing functions dropped dramatically and the range of activities which computer type machines could handle rose. The transformation of the computer from a costly end-product to a miniaturized chip has led to a new generation of electronic office products which compliment and in many cases replace mainframe computers. Such products include electronic typewriters, word processors, mini and micro computers, intelligent terminals and programmable copying machines. Although Canada does not have an indigenous mainframe industry, there are some domestic firms which are highly competitive in some of the new electronic office products such as word processors and intelligent terminals.

Potentially one of the most important areas of electronic application is in manufacturing and resource industries. The extension of electronic intelligence to conventional industrial equipment enables far greater precision in the monitoring and control of industrial processes. The impact of microelectronics on industrial productivity has been widely recognized and both the use and production of electronic instruments have been encouraged by a number of government programs. It is difficult to summarize the product composition of the instruments sub-sector because it is so extensive. However, some of the applications of electronic instruments in Canadian industry include material handling systems in the mining, steel and cement industries, process control systems in steel and pulp and paper and geophysical survey equipment. Although information is scarce on Canadian manufacturing capacity in these areas, there is evidence that in certain resource based activities such as lumber production, Canadian firms have developed important electronically operated machine tools[8].

For statistical convenience electronic systems have been included in the instruments sub-sector. In reality electronic systems represent a composite of different sub-sector products, combining elements of telecommunications, computer and instrumentation technology. Electronic systems are now widely employed for dealing with complex monitoring and simulation problems that arise in air and marine traffic control, rapid transit systems, gas and electric power distribution networks as well as in a number of defense and aerospace applications. Typically electronic systems involve the integration of a number of highly specialized products and for this reason system sales frequently involve a consortium of firms linked together through sub-contracting. There are a number of Canadian firms which produce state of the art components for electronic systems which are competitive in world markets. However, there is no single Canadian firm which has the capacity to produce an entire system such as a harbour control system and there has been some difficulty in organizing consortia to bring together various sub-system producers[9].

The remaining industry sub-sector, consumer products, consists of televisions, radios, tape recorders and other home entertainment products and household appliances. Unlike other sub-sectors, consumer products rely largely on analogue circuitry and thus have remained on the periphery of the many technical advances in digital electronics. For example, the cathode ray picture tube in television receivers is one of the last remnants of a largely defunct tube technology, rendered obsolete in most other areas of the industry by the development of semi-conductors. Thus in some respects the sector has been isolated from the mainstream of the industry and this is reflected in the prices of consumer products relative to the secular decline in the price of all other electronic products. However, recent developments in semi-conductor technology, involving very large scale integration and liquid crystal displays have advanced certain products such as television onto the threshold of digital conversion. This branch of the Canadian electronics industry has undergone extensive restructuring throughout the last decade. For the most part it consists of subsidiaries of large multinational firms.

INDUSTRY STRUCTURE

The Domestic Market

By international standards the Canadian market for electronic products is comparatively small, measuring only one tenth the size of the American market and one fifth the size of the Japanese market. Domestic consumption of electronic goods in Canada has grown from 1,5 billion dollars in 1970 to over 4 billion dollars in 1978. This increase represents an average annual rate of growth of 13.8%. A breakdown of the domestic market by industry sub-sector is shown in Table 1. Areas of rapid market growth include electronic instrumentation and computers and other electronic office equipment. The latter has nearly quadrupled since 1970 and has replaced telecommunications as the largest segment of the domestic electronics market.

In interpreting data expressed in nominal dollars, it is important to note that the prices of most electronic products during the 1970's have either dropped or increased at a rate significantly less than the rate of inflation. Unfortunately industry selling price indexes are not available at the desired level of aggregation. Nevertheless, it is reasonable to assume that nominal estimates understate the real growth that has occurred in the industry over the last decade.

Market Concentration

As of 1975 the industry contained 712 firms, ranging in size from annual sales of less than a million dollars to sales of nearly one billion. The vast majority of firms in the industry are extremely small in relation to the size of foreign competitors, many of whom are widely diversified multinationals. Firms with annual sales of less than a million include nearly 70% of the total number of firms in the industry although they account for only 3% of industry shipments. This contrasts sharply with the contribution of the sector's largest firm, Northern Telecom, which accounted for 30% of industry sales. However, in an international context Northern Telecom would be ranked as only a moderate sized firm.

Concentration ratios derived from the following size distribution of firms in the industry suggests the presence of a loosely oligopolistic structure, with the eight largest firms accounting for 51% of industry sales. In view of the industry's wide exposure to trade, concentration figures may not necessarily reflect the market power of larger domestic firms. The potential for monopolistic pricing among the industry's eight largest firms is mitigated by the threat of potential increases in the level of import penetration of the domestic market. Moreover, the export intensity of the industry, particularly among its larger firms, enables competitive forces in international markets to affect firm pricing practices in the domestic market.

Table 1

Estimates of Apparent Domestic Market for Electronic Goods in Canada 1970-1978*

(millions of dollars)

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978	AACR (%)
Telecommunications	442	380	544	631	675	827	834	938	831	10.1
Consumer Products	311	369	515	573	603	511	615	548	611	10.0
Components	335	385	406	495	619	473	581	582	748	11.9
Computers and Office Equipment	370	420	532	547	677	761	886	938	1275	17.2
Instruments & Systems	-	-	-	-	103	152	167	203	241	24.5
All Electronics**	1458	1580	2020	2256	2822	2907	3240	3439	4003	13.8

* Apparent Domestic Market = Shipments + Imports - Exports

** Market size estimates for All Electronics were determined on a SIC basis and exceed the sum of sub-sector markets. The discrepancy is due to the fact that not all of industry shipments could be identified as shipments of specific ICC products which form the basis for sub-sector estimates.

Source: Statistics Canada; Catalogue 31-211, 65-004, 65-007, Canadian Electronics Engineering.

Table 2

Distribution of Company Size by Sales (1975)

Annual Sales ($ millions)	No. of Firms	Total Sales ($ millions)	% of Total Sales
200 - 1000	1	971	30
50 - 200	7	680	21
1 - 50	213	1508	46
0 - 1	491	91	3
	712	3250	100

Source: The Canadian Electronics Industry—Sector Profile, Department of Industry, Trade and Commerce. Data includes the manufacture and distribution of non-electronic products as well.

Integration

With the exception of a few telecommunication firms, there is relatively little vertical integration in the Canadian electronics industry. Companies such as Northern Telecom and Mitel have developed in-house component divisions which produce specilized integrated circuits for their telecommunication equipment. Northern Telecom is also directly linked to Bell Canada which is by far the largest domestic user of such equipment. The absence of more widespread integration in the industry contrasts sharply with industrial practices in other countries. In the United States for example, both backward and forward linked integration is common among large electronic firms. It is estimated that the in-house production of integrated circuits by three end-product manufacturers, IBM, Western Electric and Hewlett Packard, represents roughly one third of American integrated circuit production. Furthermore, one of the largest U.S. component firms, Texas Instruments, has become a major producer of electronic consumer and office products.

The incidence of integration is similarly high in both the European and Japanese electronics industries. In Japan the major semiconductor producers such as Toshiba, Matsushita, Nippon Electric, Sony and Hitachi are all world scale producers of either computers, telecommunication equipment or electronic consumer products. In Europe, it is common for large national end-product suppliers to account for the bulk of semi-conductor production. Integration in the European and Japanese industries is particularly interesting because much of it has been encouraged by domestic governments. Underlying these policies is the belief that there are substantial economies of scale in the production and development of electronic goods and that very large and integrated firms are necessary to achieve minimum efficient scale (MES).

Scale Economies

Economies of scale vary across the different branches of the industry. Scale economies are found in production, research and development, marketing and finance. Both static and dynamic production economies exist within the industry, although the later appears to be more prevalent. In addition, there are economies of firm size associated with the diversification of risk in research and development and the distribution of large marketing costs resulting from the rapid rate of obsolescence of electronic goods. The distribution of costs in the industry, which are heavily weighed toward R&D and marketing, emphasize firm size economies. For new products, it is not uncommon for these types of expenditures to comprise over half of the product's price.

Static production economies, found in plant size and length of production run, are limited in the industry by the highly customized nature of many electronic products and the absence of standardized production techniques. Nonetheless, the manufacture of more mature products often involves assembly line type production which yields economies in plant size. In television manufacturing, for example, MES requires annual production runs of between 300,000 to 500,000 sets[12]. Similar production based economies of scale exist in the manufacture of radios and other electronic consumer products.

There are substantial economies of scale in the mainframe computer industry. Brock (1975) estimates that a minimum investment of nearly 1 billion dollars was required to enter the American mainframe market during the early 1970's. The most significant scale economies were associated with non-production costs; finance, marketing, service and research and development.

It should be noted however, that economies of firm size are comparatively minor in other areas of the electronic office equipment market. Industry estimates suggest that an initial investment as low as 5 million dollars is adequate to enter the mini computer, word processor or electronic typewriter segment of the market[13]. The rapid growth in these markets has led to a recent influx of entrants into the computer and electronic office products sub-sector. There are currently over a hundred firms producing computer type equipment in Canada. However, it is expected that as the technology and products become more standardized, minimum investment and MES will rise.

In semiconductors, scale economies until very recently have been modest. However, Wilson et al. (1980) argue that the real cost of establishing a basic wafer fabrication plant trippled between 1965 and 1975 and is expected to double again between 1979 and 1985. It is estimated that a minimum investment of between 10-34 million dollars, depending on component type, is required to set up an efficient sized operation in the U.S. semiconductor industry.

Another significant scale factor in the electronics industry is the widespread incidence of learning economies. Learning is generally measured through the relationship between real unit costs and cumulative output of a particular product or generations of products which fulfill the same function. These economies have been broadly identified at both the industry and firm level (Tilton 1971, Boston Consulting Group 1972, Noyce 1977 and Scherer 1980)[14]. On average these studies have shown that real unit costs fall between 20-30 per cent with every doubling in cumulative output. There is partial evidence of learning in the Canadian industry. A regression test found that labour productivity increases 20 per cent with every doubling in cumulative sales. Insufficient information on total factor productivity did not permit an analysis of the relationship between cumulative sales and units costs. (See Statistical Appendix - A Regression Estimate of a Learning Curve).

The influence of learning phenomena on industry structure is ambiguous. The structural impact of learning economies depend crucially on the parameters of the learning curve and the nature of the learning process itself. Spence (1980) argues that in some cases the cost advantages associated with pronounced learning economies may justify natural monopolies or at least highly concentrated industries[15]. Learning curves which are moderately sloped and extend over a wide range of cumulative output before reaching an asymptote generate cost advantages which are consistent with a concentration argument. However, steeply sloped curves that quickly approach an asymptote enable latecomers with relatively small levels of cumulative output to achieve cost parity with more mature producers. Therefore a case for concentration cannot be generalized for all curves.

The impact of dynamic scale economies on market concentration is further complicated by the rapid rate of product obsolescence which is commonly associated with learning intensive industries. On one hand, rapid technological change may truncate product specific learning and thereby cancel the advantages of coming first (Tilton, Scherer)[16]. On the other hand, learning may take place across similar products so that even with technical change, an inverse relationship between cumulative output and unit costs may persist over a continuum of product developments. In this case, learning would provide more enduring cost advantages and tend to contribute to industrial concentration.

Tariff and Non-Tariff Barriers

Despite the increasing internationalization of the industry, trade flows have been impeded by the widespread use of tariff and non-tariff barriers. While trade policies differ among producing nations, a recurrent pattern in all electronic industries is the growing incidence of non-tariff barriers, chiefly in the form of public procurement practices. Procurement policy, conferring strong support for domestic manufacturers, has effectively closed most European as well as Japanese telecommunication markets to Canadian exports. Similar practices restrict imports of computers and other electronic office products. Japan not only imposes quotas on imports but also restricts domestic sales of foreign controlled subsidiaries. Britain and France have both reserved sizable segments of their domestic markets for national producers such as ICL and Cii-HB through procurement regulations. Swedish procurement policy in word and data processing equipment parallels British and French policy through its endorsement of Data SAAB, the large Swedish computer manufacturer.

Tariffs seem to play a less important role in the protection of domestic markets. European tariffs on electronic goods are modest but since they do not apply to ECC members, North American producers are placed at a disadvantage. American tariff rates are probably the lowest of all major producing countries but the use of non-tariff barriers is on the upswing. A Buy American procurement policy allows domestic manufacturers a minimum 10% cost advantage over competing imports. Moreover, the United States has imposed quotas on the importation of consumer goods such as televisions and radios and has recently insisted on a minimum of 50% domestic content in telecommunications equipment. The latter barrier has had a significant impact on the Canadian telecommunications industry since the American independent (non-AT&T) market is one of the largest export markets available to Canadian producers[17]. It is likely that restrictions on foreign content led Northern Telecom to locate many of its new manufacturing facilities in the United States.

Canadian trade policy has afforded moderate to high protection for the industry as a whole. A distinctive feature of Canadian protectionism has been its reliance on tariff as opposed to non-tariff barriers. On average, nominal tariff rates are set at around 15% but vary widely across products. It is evident that at least in some areas the current tariff structure bears little relationship to the present composition of the industry. A number of anomalies may be noted in this respect. Imports of computers and components are taxed at 15-20% even though there is little domestic production of these products. In these cases it seems that the tariff merely serves to raise production costs of domestic data processing firms and electronic end-product manufacturers who use these products as inputs.

Procurement policy in Canada is generally less protective than in Japan, Europe or the United States. Nonetheless, electronic goods account for a sizable proportion of federal procurement expenditures given the government's widespread need for electronic products in defense, data processing and communications. In 1974 federal procurement accounted for roughly 12% of the value of shipments from SIC 335 and 10% from SIC 318[18]. It is estimated that between 1972-1977 federal government procurement of electronic goods has grown steadily at an average annual rate of 20%. In some cases procurement has been used effectively to foster industrial development. Northern Telecom benefited substantially from federal and provincial telecommunication mandates given to its parent company Bell Canada and AES Data seems to have benefited from the federal government's undeclared Buy Canadian Policy through its purchase of word processors.

However, it should be noted that the combined level of federal and provincial public sector demand represents no more than 20-25% of the total domestic electronics market in Canada. By comparison, it is likely that the 1980 level of government demand for electronic products in the United States exceeded the size of the entire Canadian domestic market.

Foreign Ownership

The Canadian electronics industry has the highest percentage of foreign-owned firms among the major producing nations. Of the industry's 100 largest firms, 72 are foreign-owned. In total, foreign-owned firms account for 20% of the 712 firms in the industry, representing 55% of industry shipments. The importance of foreign-owned firms in relation to industry output would increase dramatically if Northern Telecom's sales were excluded; in such a case, foreign-owned firms would account for 80% of industry shipments.

Virtually all foreign-owned enterprises in the industry are subsidiaries of multinational corporations. Many have located in Canada in response to domestic tariffs, establishing branch plants in order to gain duty free access to the Canadian market. Over the course of the last decade or so, many of these plants have closed due to both domestic and international factors. In some cases only a retailing operation remains, in others, product mandates have been allotted to Canadian subsidiaries permitting some measure of specialization.

Generally, foreign-owned firms have tended to concentrate in the more scale sensitive areas of the industry. This is true particularly in cases where large scale economies have discouraged the emergence of domestic suppliers, i.e. television manufacturing and mainframe computers. The presence of foreign ownership is less pronounced among manufacturers of new, technology intensive products. In these areas domestic firms prevail.

Research and Development

The electronics industry is by far the most R&D intensive industry in Canada. The industry accounts for nearly one quarter of total industrial R&D expenditures and employes a comparable percentage of industrial R&D personnel. R&D expenditure per worker in electronics is roughly three times the average found in Canadian industry and R&D spending as a percentage of sales is as much as 5 times greater than the average for all manufacturing industries.

The bulk of R&D spending in the industry is concentrated in the telecommunications sector. In 1977 the combined level of research spending in this sub-sector amounted to 180 million dollars, of which approximately 70 per cent was funded from the private sector. It is estimated that Bell-Northern accounted for roughly 68 per cent of privately financed research and development expenditures. Current estimates of R&D expenditures by Bell-Northern range between 200-250 million dollars.

R&D expenditures are of a lesser magnitude, but still relatively high, in the computer and electronic office equipment sector (SIC 318). Table 3 shows the absolute level of spending between 1971-1977 and its relationship to industry shipments. The single largest investor in R&D was IBM Canada which accounted for 40 per cent of the industry total. Nevertheless, as a percentage of sales, R&D spending by the Canadian subsidiary was far below IBM's international average.

The only sector of the electronics industry that is not R&D intensive is the consumer products sub-sector. According to a recent Statistics Canada survey of industrial research and development establishments there

Table 3

Computers and Other Electronic Office Products Sub-Sector

	R&D Expenditures (millions of dollars)		R&D Expenditures As a % of Shipments (%)	
	Current	Total*	Current/Shipments	Total Shipments
1971	13.9	21.6	6.85	10.64
1972	22.5	26.6	8.59	10.15
1973	21.3	25.3	7.42	8.81
1974	21.3	29.1	6.16	8.41
1975	24.8	31.2	6.65	8.36
1976	26.8	32.7	6.19	7.55
1977	31.0	35.9	6.89	7.98

* Includes capital expenditures

Source: Electronics Industry Sub-Sector Profile: Computers and Office Machines, Electronics Task Force Secretariat, Department of Industry, Trade and Commerce.

is only one firm in the sector which is currently involved in R&D[19]. During the early 1970's a number of foreign-owned subsidiaries maintained a modest level of R&D spending. However, many of these firms have since left the industry and remaining firms have undergone extensive rationalization which has entailed a discontinuation of R&D work in Canada.

Employment

Employment in the electronics industry has fallen from slightly under 68,000 in 1970 to approximately 50,000 in 1978 (Table 4). On a per annum basis, total employment has declined at an average rate of 3.7 per cent.

To a great extent the statistics in Table 4 can be interpreted as part of a long-run trend toward declining employment in the industry. This trend parallels the continuing shift in value-added from hardware to software which is more labour intensive and which is statistically accounted for among service industries. The trend has occurred over a succession of different generations of component technology. Each generation of technology (i.e. transistors, integrated circuits, very large scale integrated circuits) has dramatically reduced the cost of hardware and the amount of labour required to produce it.

A second factor that has adversely affected employment has been the widespread incidence of rationalization in the industry. This is particularly evident over the last decade in the consumer products sub-sector where employment has declined at an annual average rate of 12.2 percent.

Despite the industry wide reduction in total employment, many firms are currently experiencing an acute shortage of engineers, computer scientists and other highly skilled labour. Faced with domestic labour shortages in this area, the industry has been compelled to import technical personnel from the United States and Europe.

Table 4

Employment in the Canadian Electronics Industry

Year	SIC 318	SIC 334	SIC 335	Total
1970	15769	7922	45213	68904
1971	8696	7737	44582	61015
1972	10134	8136	40148	58416
1973	10866	8748	43719	63333
1974	11397	8259	44281	63937
1975	9613	7036	42041	58960
1976	9758	6347	38467	54572
1977	8635	3382	36676	48693
1978	9629	2332	37895	49856

Average Annual Employment Growth Rates 1970-1978

SIC 318 - Office and Store Machinery	-2.2%
SIC 334 - Household Radio and Television Receivers	-12.2%
SIC 335 - Communications Equipment	- 2.1%
Total - Electronics Industry	- 3.7%

Source: Statistics Canada; Cat. No. 42-216, 43-205, 43-206

INDUSTRY PERFORMANCE

Productivity

Productivity is the most widely recognised measure of industrial performance. Measured against this criteria the performance of the electronics industry has been impressive. Two aspects of industrial productivity are presented in Table 5, the level of productivity and its rate of growth. For purposes of comparison, the electronics industry has been disaggregated on a SIC basis, since productivity data are not available at the individual sub-sector level.

Real Domestic Product per man-hour in all three SICs is significantly greater than the average level found in Canadian manufacturing industries. In SIC 318 and 334, productivity has grown to a level roughly three times the average in manufacturing. RDP per man-hour in SIC 335 remained approximately 1.5 times greater than the industrial average between 1971-1979.

Turning to growth rates, the comparison between electronic industries and manufacturing industries is no less striking. The annual average rate of growth in RDP per man-hour in Canadian manufacturing was 2.9%. By contrast, the rate of growth in productivity in SIC 318 and SIC 334 was four times as great, averaging 11.7% and 11.6% respectively. Productivity growth in SIC 335 lagged behind the average in manufacturing, although the actual level remained higher. The poorer performance of SIC 335 is curious in light of the fact that it contains the telecommunications sub-sector, an area of traditional strength in the Canadian electronics industry. Unfortunately it is not possible to analyze productivity in telecommunications separately because the SIC data cannot be disaggregated.

Productivity performance reflects a variety of factors. Obviously one factor is the rapid pace of technical change in the industry. It is also likely that the restructuring undertaken by many foreign-owned subsidiaries

Table 5

Real Domestic Product Per Man-Hour

(constant 1971 dollars)

Year	SIC 318	SIC 334	SIC 335	All Manufacturing Industries
1971	11.08	9.95	8.85	5.96
1972	12.94	11.78	9.14	6.22
1973	11.97	12.19	9.43	6.55
1974	12.32	12.50	9.71	6.66
1975	16.43	14.71	10.01	6.48
1976	17.99	16.98	10.32	6.80
1977	21.49	27.27	10.64	7.15
1978	22.88	27.69	9.91	7.37
1979	25.71	22.88	10.39	7.45
AACR (%)	11.7	11.6	2.1	2.9

Source: Statistics Canada; Catalogue 42-216, 43-205, 43-206, 61-213, 61-005

See Table 4 for SIC codes.

classified in SIC 318 and 334 had a positive influence on the industry's overall performance.

Trade

During the last two decades, the major electronic industries in the world have become increasingly internationalised with trade playing a dominant role in marketing aud production strategies. Accordingly, aspects of trade performance are commonly noted in international industrial comparisons. In part the internationalization of the industry reflects the degree of specialization found among electronic producers which has become necessary given the tremendous increase in the variety and type of electronic goods. The growing volume of intra-industry trade is shown in the growth of both imports and exports in most industrialized countries. Table 6 notes the simultaneous increase in levels of import penetration and in the ratio of exports to shipments in virtually all major producing nations. With the exception of Japan imports have risen substantially as a percentage of domestic electronic markets, representing roughly half of the market in Canada, W. Germany and Britain. At the same time the importance of exports in industry shipments has risen in all the major electronic industries. The ratio of exports to shipments ranged from 20% to 50%. Generally industries linked to smaller domestic markets such as Canada, West Germany and France recorded the largest increases in this ratio.

Although trade patterns in Canada are similar to those in other countries, on the whole the trade performance of the Canadian industry is mixed. The trade deficit in electronic products has risen from 342 million in 1970 to over 2 billion in 1979. If viewed by sub-sectors (Table 7), only telecommunications managed not to have a growing trade deficit during the 1970's. The largest deficit, approximately one billion dollars in 1979, occurred in computers and electronic office equipment. Serious trade imbalances also exist in the components and consumer products sub-sectors which posted deficits of 789 million dollars and 467 million dollars respectively in 1979.

A further breakdown of industry trade by sector imports and exports is provided in Table 8. On average all electronic imports grew at an annual rate of 19.1% while exports grew by 15.2%. Since imports grew from a substantially large base, the difference between the rate of export and import growth is magnified in the absolute level of the deficit. If exports are considered apart from the trade balance, the performance of the industry compares favourably with other manufacturing industries in Canada. Moreover Table 9 indicates an industry-wide increase in the ratio of exports to shipments over the last decade. By 1978 exports accounted for over half of shipments in the computer, consumer products and electronic systems sub-sectors.

Import penetration, on the other hand, has increased significantly in all industry sub-sectors. Imports by 1978 represented just under 65% of the total domestic electronics market and accounted for as much as 87% of individual sub-sector markets. In some cases, telecommunications and consumer products, the level of import penetration has doubled since 1970.

A Synopsis of Industry Performance

In reviewing structure and performance, a number of stylized facts arise which suggest that the industry has become increasingly rationalized over the last decade. This is manifest in the rapid growth in productivity, coupled with declining employment and increasing levels of intra-industry trade. If indeed rationalization has taken place, then there is reason to believe that the observed increases in the ratio of exports to shipments is related to greater import penetration. That is, it is possible to argue that domestic producers are becoming more specialized, competing effectively in international markets and at home with their specialized products and leaving the balance of the market to foreign producers. From the standpoint of performance, the trade data are encouraging since the relevant consideration is not the overall trade balance, but the growth in exports of products which the industry has chosen to specialize in.

Table 6

Electronics - International Trade

Imports as a % of Apparent Domestic Market

	1965	1975
Canada	36.0	53.6
United States	3.6	13.7
W. Germany	24.3	48.6
Britain	21.1	45.1
France	26.0	32.5
Japan	8.1	7.5

Exports as a % of Shipments

	1965	1975
Canada	20.2	34.3
United States	7.9	19.8
W. Germany	37.5	57.8
Britain	29.8	46.3
France	24.3	28.6
Japan	23.7	27.5

Source: OECD

Table 7

Balance of Trade

(millions of dollars)

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Telecommunications	55	10	-15	-20	-20	-21	-20	-106	-66	238
Consumer Products	-98	-113	-206	-221	-287	-237	-361	-382	-439	-467
Components	-100	-114	-178	-217	-281	-226	-298	-339	-426	-789
Computers and Office Equipment	-179	-218	-270	-260	-331	-388	-474	-521	-728	-964
Instruments & Systems	-20	-26	-24	-10	-17	-19	-39	-67	-94	-85
Total	-342	-462	-692	-728	-936	-892	-1191	-1415	-1752	-2068

Source: Statistics Canada; Catalogue 65-004, 65-007

Table 8

Exports and Imports by Sub-Sector

(millions of dollars)

Exports

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	AAGR (%)
Telecommunications	141	117	102	129	164	195	231	207	259	437	16.1
Consumer Products	27	29	26	31	32	26	31	54	94	103	19.7
Components	63	71	90	140	155	129	133	141	203	220	10.7
Computers and Office Equipment	57	67	85	136	151	125	129	137	198	213	10.7
Instruments & Systems	46	40	43	68	69	80	71	60	78	113	13.0
Total	335	324	347	504	572	556	594	599	832	1086	15.2

Imports

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	AAGR (%)
Telecommunications	86	197	118	149	184	216	250	313	324	199	17.2
Consumer Products	125	142	231	252	320	263	392	436	533	570	20.4
Components	163	184	267	357	437	355	431	481	629	1009	24.4
Computers and Office Equipment	237	286	355	396	482	514	603	657	926	1177	19.9
Instruments & Systems	66	66	68	78	86	100	110	127	172	199	24.0
Total	677	785	1039	1232	1509	1448	1785	2013	2585	3154	19.1

Source: Statistics Canada; Catalogue 65-004, 65-007

Table 9

(percentages)

Ratio of Imports to Domestic Market

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978
Telecommunications	20.4	28.2	21.7	23.6	27.2	26.1	30.0	43.1	39.0
Consumer Products	40.2	38.5	44.9	44.0	53.1	51.5	63.7	79.6	87.2
Components	48.4	48.1	65.8	72.1	70.6	75.1	74.2	82.6	84.1
Computers and Office Equipment	64.1	68.1	66.7	72.4	72.2	67.5	68.1	70.0	72.6
Instruments & Systems	–	–	–	–	83.5	65.8	65.9	62.6	71.4
All Electronics	46.4	49.7	51.4	54.6	53.5	49.8	55.1	54.0	64.6

Ratio of Exports to Shipments

Sector	1970	1971	1972	1973	1974	1975	1976	1977	1978
Telecommunications	29.6	28.2	21.7	23.6	27.2	26.1	30.0	43.1	39.0
Consumer Products	12.7	11.3	8.4	8.8	10.2	9.5	12.2	32.5	54.7
Components	26.8	26.2	39.5	50.4	45.9	52.2	47.0	58.3	63.0
Computers and Office Equipment	29.8	33.2	32.4	47.3	43.6	33.5	31.3	32.9	36.2
Instruments & Systems	–	–	–	–	81.1	60.1	55.5	44.1	53.1
All Electronics	23.0	20.5	26.1	33.0	34.2	32.1	33.3	35.4	43.1

Source: Statistics Canada; Catalogue 31-211, 42-216, 43-205, 43-206, 65-004, 65-007, Canadian Electronics Engineering.

APPENDIX

Statistical Sources and Methodology

Five data sources were used in compiling statistical estimates for the industry. Three of these sources, SIC, ICC and Commodity Trade Classifications, originated from Statistics Canada series. Estimates from industry trade journals and the Department of Industry, Trade and Commerce were also used. The limited concordance between these series prompted a dual classification of the industry. One classification is based on product type sub-sectors and the other on three digit SICs. Sub-sector estimates were derived through the aggregation of specific product data. Individual product information with respect to shipments, imports and exports were obtained from several sources. Shipment estimates were largely provided by ICC data at the three, four and five digit level. In addition, industry estimates published in Canadian Electronics Engineering were used. Sub-sector trade data were complied through aggregating import and export levels for individual products. This data was furnished from Statistics Canada's trade series contained in Catalogue 65-004, Exports by Commodities and 65-007, Imports by Commodities.

SIC and sub-sector coverage may be matched as follows. SIC 318, Office and Store Machinery, corresponds to the Computer and Other Electronic Office Equipment sub-sector. SIC 334, Manufacturers of Household Radio and Television Receivers, refers to the Consumer Products sub-sector. Finally, SIC 335, Communications Equipment Manufacturers, encompasses the telecommunications, components and elements of the electronic instrument and systems sub-sectors. Some products in the instruments sub-sector are classified by their end-use and thus do not appear in SIC 335. Instead, they are hidden in the output of a number of other SICs. For this reason it seems safe to assume that the sub-sector is larger than indicated by the estimates provided in this study.

Statistics Canada References

Catalogue 31-211	Products Shipped by Canadian Manufacturers
Catalogue 42-216	Office and Store Machinery Manufacturers
Catalogue 43-205	Manufactuers of Household Radio and Television Receivers
Catalogue 43-206	Communications Equipment Manufacturers
Catalogue 61-005	Indexes of Real Domestic Product by Industry
Catalogue 65-004	Exports by Commodities
Catalogue 65-007	Imports by Commodities

A Regression Estimate of a Learning Curve

From company interviews and questionnaires information was obtained on total output and employment. Several of the companies interviewed are specialized in the production of a particular good or set of closely related products. One firm provided sufficient historical data to permit an estimate of a learning curve. This was carried out by an ordinary least squares regression with labour productivity (the log of output per employee) as the dependent variable and the log of cumulative output as the sole independent variable. Although one would ideally want to control for other influences on productivity this was not possible given the data base. The data provided information on cumulative sales and employment on an annual basis for five succeeding years. Thus there are five data points in the sample.

The results of the analysis are presented in the following table. The coefficient of cumulative sales is positive and significant at the 95 per cent level. Since the regression is run in logarithms, this coefficient can be interpreted as an elasticity. Its value, .20, indicates that a 20 per cent increase in labour productivity results from every doubling in cumulative output. It should be noted that the functional form of the regression assumes a constant learning speed. If more observations had been available, it would have been useful to allow learning speed to vary with cumulative output and to test for the presence of an asymptote to the learning curve.

Table 10

Regression Results

Dependent Variable: log (sales/employment) in year t

Independent Variable: log (cumulative sales) at end of year t-1

t = 1976, 1977, 1978, 1979, 1980

Estimated Coefficient of Independent Variable: 0.2014

T Statistic: 3.963

Estimated Value of Intercept: 7.239

T Statistic (for intercept): 7.805

$R^2 = 0.8396$

$F(1,3) = 15.702$

Footnotes

1. The shift from analogue to digital circuitry is closely related to the miniaturisation of circuit components. Unlike digital circuits, analogue systems cannot accommodate the large number of microcircuits found in modern electronic devices. See R. Noyce, Microelectronics, Scientific American, 237, No. 3., pp. 62-69.

2. R. Wilson, P. Ashton, and T. Egan, 1980, Innovation, Competition and Government Policy in The Semiconductor Industry (Lexington, Mass. D.C., Heath).

3. For a discussion of integrated circuits and their properties see I. Barron and R. Curnow, 1979, The Future with Microelectronics (London, Francis Pinter); E. Braun and S. MacDonald, 1978, Revolution in Miniature, (Cambridge, Cambridge University Press); and M. Orme, 1980, Micros: A Pervasive Force (London, Associated Business Press).

4. For example, Barron and Curnow argue in a report for the British government that Britain must have a components industry if it is to achieve commercial success in electronic end-products. Although this recommendation is questionable, it reflects a widespread sentiment in the industry concerning the vital linkage between developments in semiconductor technology and the future course of electronic applications. See I. Barron and R. Curnow, 1979, The Future with Microelectronics (London, Francis Pinter).

5. The only major component firm to have existed in Canada was Microsystems International . The firm was established by the federal government for reasons similar to those expressed in the Barron and Curnow report. After operating for a brief period the firm was closed in 1975 due to a slump in the world semiconductor market and the apparent inability of the firm to complete effectively with large multinational component firms.

6. See H. Hinden, 1981 "Controlling the Electronic Office: PBXs Make Their Move", Electronics, April 7, 1981.

7. Witness the recent decision in the United States to allow AT&T to enter the computer market and IBM to compete in telecommunications. This reverses a longstanding ruling by the Justice Department in 1956 which prohibited AT&T and its manufacturing subsidiary Western Electric from competing in areas of the electronics industry other than telecommunications.

8. Globe and Mail May 4, 1981.

9. Although there have been isolated instances where consortia have been formed (i.e. in the export of electronically automated postal systems), on the whole there has been little success in integrating the products of sub-system producers in an entire system package for export. A number of system firms interviewed felt that the greatest obstacle to establishing an export consortium is the absence of a domestic firm large enough to undertake the responsibility for putting together an entire system. Therefore most sub-system firms rely on sub-contracts from large multinational system firms.

10. Barring the possibility of dumping, the domestic price cannot exceed the export price. Thus firms such as Northern Telecom which export as much as 50% of their domestic production may be discouraged from setting monopolistic prices in the domestic market since this would adversely affect the competitiveness of their exports on international markets.

11. See R. Wilson, P. Ashton, and T. Egan, 1980, op. cit. In addition, there is evidence of widespread integration among mainframe computer manufacturers which have integrated backwards into component production. It is currently estimated that IBM meets 80% of its demand for integrated circuits from in-house production. In doing so, IBM, has become the world's largest producer of integrated circuits without having ever sold an integrated circuit on the open market. Aside from IBM there are a number of other American based computer firms which have become increasingly integrated. For example, Honeywell produces 20% of its own integrated circuits needs, NCR 40%, Sperry Rand 20% and Control Data 20-25%. See F. Kline, 1980, Computers: Key to Productivity in the Eighties (New York, Drexel Lambert, Burnham).

12. Electronics Task Force Secretariat 1978, Sub-Sector Profile: Television Manufacturing (Ottawa, Department of Industry, Trade and Commerce); Charles Rivers Associates, 1980, International Technological Competitiveness Television Receivers and Semiconductors (Washington, National Science Foundation).

13. These estimates along with the prediction that MES will rise in the future are based on interviews with firms in the industry.

14. J. Tilton, 1971, International Diffusion of Technology; The Case of Semiconductors (Washington D.C. , The Brookings Institute): R. Noyce. 1977. op. cit.. Boston Consulting Group, 1972. Perspectives on Experience; F. Scherer, 1980, Industrial Market Structure and Economic Performance (Chicago, Rand McNally).

15. A. Spence, 1980, The Learning Curve and Competition, Bell Journal of Economics (12) 1.

16. J. Tilton, 1971, op. cit., F. Scherer, 1980 op. cit.

17. One of the more important American non-tariff barriers is the domestic content rules governing procurement by the Rural Electrification Authority which regulates a sizable segment of the American independent phone market.

18. Electronics Task Force Secretariat, 1978, Government Procurement (Ottawa, Department of Industry, Trade and Commerce).

19. Statistics Canada, Annual Science Statistics, (Ottawa, Statistics Canada).

CHAPTER 2

RATIONALIZATION AND INDUSTRIAL POLICY

Over the last two decades the electronics industry has grown from relative obscurity into a major part of secondary manufacturing in Canada. This evolution has entailed a number of structural changes which have enabled segments of the industry to perform competitively on international markets. Many of these changes have occurred in response to problems which are endemic to Canadian manufacturing. Therefore it is useful to relate rationalization in the industry to some general issues of industrial performance in a small protected domestic market.

Protection and Structural Change

Market size influences industrial efficiency through its potential impact on the realization of scale economies. Small protected markets may impede the exhaustion of scale economies and encourage sub-optimal capacity in domestic industry. Eastman and Stykolt (1967) found the widespread incidence of sub-optimal capcity in a number of Canadian manufacturing industries related to the size and level of protection of the domestic market[1]. Subsequent studies by Daly et al. (1968) and Caves, (1975)[2] have identified scale inefficiencies in the length of production runs of highly diversified Canadian manufacturing plants. The greater frequency of switchover costs incurred as a result of short production runs have been commonly associated with the profusion of product types produced in a single plant. In addition, plant diversification may adversely affect scale efficiency by discouraging the adoption of specialized equipment necessary for the utilisation of best-practice techniques. Thus efficiency in the production of individual products may be compromised in order to accommodate the production of a wider range of goods.

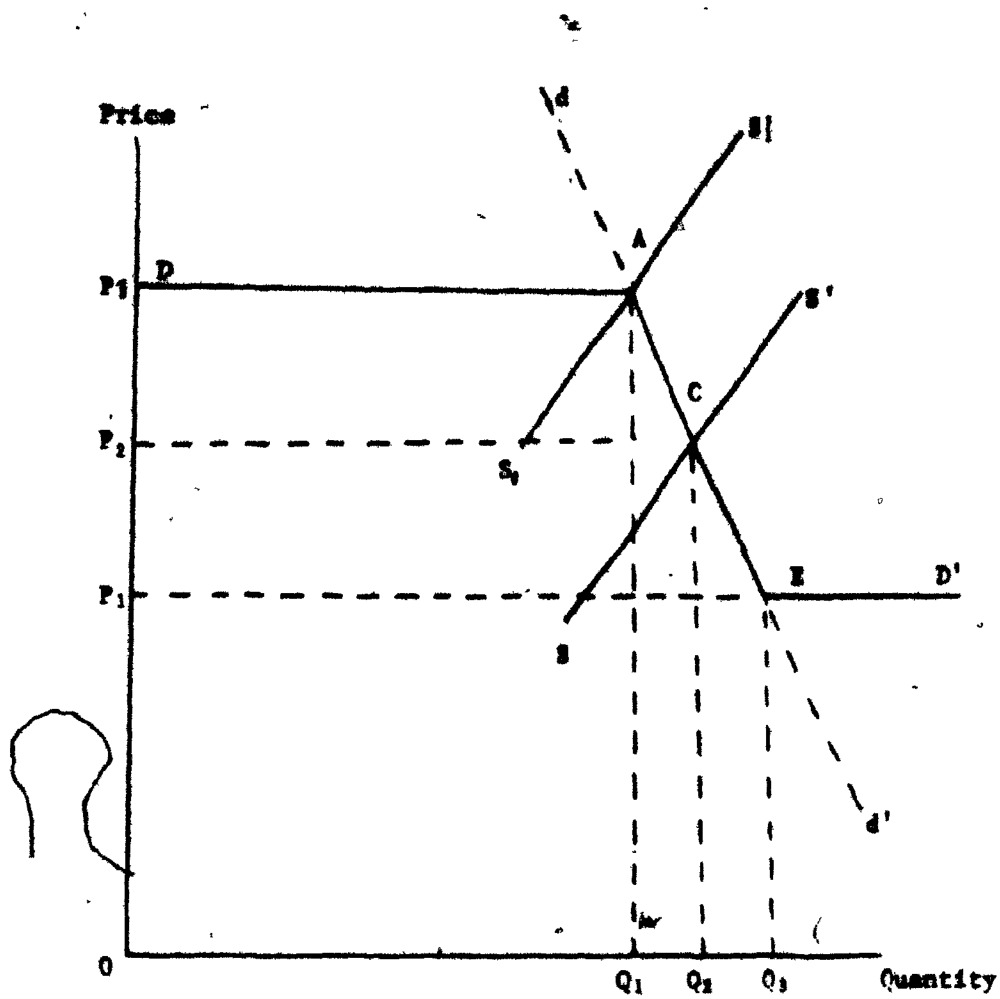
Production run diseconomies are characteristic of small protected domestic markets. In most cases plant diversification is a product of a level of domestic demand which does not permit the exploitation of economies of specialization. Thus the realization of scale efficiency through specialization may frequently involve changes in tariffs and other structural factors which facilitate access by domestic firms to international markets. A number of these changes are considered in the following discussion of rationalization.

It is possible to view rationalization within the context of a model of import competition. A simplified version (Green 1980)[3] of the standard Eastman-Stykolt model illustrates some of the more salient aspects of restructuring associated with changes in the level of effective protection.

In the following diagram an industry faces a domestic market represented by the declining segment (AE) of the demand curve DAED'. The parameters of this segment, A and E, delineate the dimensions of the domestic market in relation to a range of possible domestic prices. This range is bounded by an import price barrier, OP_3, and an export price OP_1. The import price barrier sets a ceiling for the domestic price since any price level above this point permits imports to enter the domestic market. Its level is equal to the world price plus the domestic tariff and any transportation costs incurred by imports. The export price is the price which allows domestic producers to sell in foreign markets and is the minimum price which the industry need accept in the domestic market.

Let us assume that the industry in question is composed of plants of suboptimal scale operating under the protection of a domestic tariff. The industry supply curve will intersect the demand curve above point E and the industry selling price will exceed the price which facilitates exports. Consequently industry output will be restricted to the level of domestic demand. The competitive equilibrium price-output level is denoted by the point of

DIAGRAM A



intersection between the industry supply curve and the declining segment of the demand curve. C is the point at which DD' and SS' intersect where the industry produces OQ_2 units of output at a unit price of OP_2.

If the industry is an oligopoly the domestic price may deviate from the industry's minimum average cost. In this case, the industry may restrict output to OQ_1 and sell in the domestic market at a price just below OP_1 which maximizes profit subject to the constraint of the import barrier price. The existence of economic profits is likely to attract entry to the industry unless there are barriers to additions to industrial capacity. In the absence of domestic entry barriers, the addition of new firms to the industry redistributes the protected market among a larger number of domestic firms. The ensuing fragmentation of the market exacerbates scale diseconomies which in turn squeezes profit margins through increasing unit costs. Conventional theory suggests that entry to the industry will continue until price no longer exceeds minimum average cost. Thus the addition of sub-optimal capacity will eventually raise average cost to the point where there is no further incentive for entry at OP_3. This point is marked by an upward shift in the industry supply curve from SS' to P_1S_1'.

The argument suggests that protection is likely to exacerbate the problem of scale inefficiency by encouraging a greater proliferation of sub-optimal size plants in an industry. By indirectly raising average cost, the tariff can potentially leave domestic producers competitively worse off than they were, prior to protection. Thus the tariff tends to become a permanent feature since its reduction at any point in the future would threaten the existence of the domestic industry.

The displacement of domestic production by imports can be averted if rationalization can promote greater cost efficiency among domestic firms and lower the industry supply curve. Rationalization may simply involve a consolidation of productive capacity and the exit of some firms from the industry. A reversal of the entry process might sufficiently increase the market share of remaining firms to enable the achievement of larger production scales.

Rationalization may also involve greater specialization among firms in the industry. The key aspect of this adjustment is a change in the composition of industry output reflecting the concentration of production in a narrower range of goods. Specialization requires the industry to produce only a few products at a presumably efficient scale. The industry will not only supply the domestic market with those products, but in addition, will be able to sell in foreign markets. Concurrently, imports will supply the domestic market for products which the industry no longer produces. Thus a reduction in the level of protection would have precipitated a structural adjustment which permits import penetration of certain products and the development of an export industry in other products.

The model also provides some insights into the dynamics of foreign investment in a protected domestic market. Foreign investment decisions will be influenced by the juxtaposition of the import barrier price and the supply curve of the domestic industry. If tariffs prohibit the entry of competitively priced imports, multinationals may invest in domestic capacity and produce behind the tariff wall. If, on the other hand, the import barrier price drops relative to the industry selling price, foreign firms may substitute exports for foreign investment. Therefore it can be argued that tariffs attract foreign firms to the domestic industries of protected markets when they might otherwise supply those markets through trade.

Although the previous argument has been commonly cited in connection with the high degree of foreign ownership in Canadian manufacturing industries, there is reason to believe that once established, foreign-owned plants reinforce the need for further protection by exacerbating scale inefficiency and market fragmentation in domestic industry. For example, Caves (1975) found that foreign-owned manufacturing plants in Canada are significantly more diversified than resident-owned plants of comparable size[4]. Typically, foreign investment in Canadian manufacturing has established plants which produce a scaled down version of the product lines of their parent firms. Since domestic demand for individual products is limited, subsidiaries tend to concentrate the production of their entire product range in a single plant, thereby incurring diseconomies of short production runs. This practice contrasts the efficient multi-plant operations of parent firms, many of which are large and highly diversified multinationals.

Moreover, foreign-owned firms may be more prone to sustain sub-optimal size plants than domestic firms because they frequently enjoy advantages from economies of firm size. Many subsidiaries have access to a number of intangible rent yielding assets which are transferred from their parent firms at a minimal marginal cost[5]. These assets include the parent firm's technology, marketing expertise, financial leverage and brand image. The use of these assets enables foreign-owned firms to partially compensate for production run diseconomies and operate more profitably than domestic firms at a given level of sub-optimal capacity.

Lastly, foreign ownership worsens the problem of market fragmentation by recreating in Canada oligopolistic market structures which exist abroad. If one firm locates production facilities in Canada, there is a tendency for other members of a foreign oligopoly to follow. This tendency has been noted in consumer durable industries where product differentiation encourages the exploitation of the marketing skills and brand image of multinational firms (English 1964)[6].

These behavioural characteristics of foreign-owned firms draw attention to some of the adverse ramifications of foreign investment on industrial structure and performance. It is important however to distinguish between different types of foreign-owned plants and avoid generalizations regarding direct foreign investment per se. The proliferation of branch plants is a typical but not inevitable manifestation of foreign investment in Canadian manufacturing. For example, rationalized plants, in contradistinction to branch plants, may be highly specialized and scale efficient. Production in this type of plant is generally oriented toward some segment of the parent firm's international market, hence the scale of manufacturing is freed from the constraint of domestic demand. Since this constraint is often reinforced by corporate non-tariff barriers to trade,parent-subsidiary rationalization is generally dependent on the assignment of a world product mandate. The international distribution of these mandates by multinational firms is a complex phenomena involving a variety of political and economic factors. For this reason policies such as trade liberalization which discourage the maintenance of sub-optimal capacity may not necessarily induce the location of more specialized foreign-owned plants. This of course does not exclude the possibility that tariff reductions are still preferable even if large segments of an industry disappear as a result. However, it does suggest that <u>intra-industry rationalization</u> involving subsidiaries of foreign multinationals may require the use of additional industrial policy instruments to ensure that these firms undertake specialization and not simply withdraw from an industry when confronted with tariff reductions.

Evidence of Rationalization in the Electronics Industry

On the basis of available information, two sub-sectors of the electronics industry have been selected for case studies of rationalization. Both sub-sectors have undergone extensive restructuring and have substantially improved their performance over the last decade. There are two common factors which have influenced the nature and direction of structural change in these sectors. Ownership in both cases is predominately foreign, consequently restructuring has entailed the closing of some branch plants and the transformation of others into more specialized modes of production. This has led to attendant changes in the market scope of domestic industry. Secondly, rationalization has involved government intervention although the form of intervention has differed in accordance with the specific circumstances and structural characteristics of the sub-sectors involved. In the consumer products sub-sector, structural change has revolved around the Duty Remission Program and pending tariff reductions. The changes brought about by these measures can be largely explained in terms of the Eastman and Stykolt model previously described. In the second case, computers and office equipment, rationalization has been induced by sweeping technological changes and by direct government support through public procurement and investment subsidies. Despite disparate conditions, both instances highlight the importance of industrial policy in shaping structural change.

The case studies of rationalization are followed by a more general statistical test for rationalization which is predicated on the assumption that specialization is revealed in changes in the level of intra-industry trade over time. This test augments our knowledge of restructuring in areas of the electronics industry where a more detailed examination has not been possible. It also provides results which are consistent with our findings for the two sub-sector studies and may be interpreted as an additional confirmation of the hypothesis that the electronics industry has become increasingly rationalized in recent years.

Consumer Products Sub-Sector (SIC 334)

The consumer products sub-sector during the 1970's epitomized many of the structural problems associated with the protection of a small, highly fragmented domestic market. The sector's adaptation to trade liberalization and the attendant changes in industrial composition are in many respects reminiscent of the adjustment processes depicted in the Eastman-Stykolt model. Rationalization has followed a period of rapid deterioration in the industry's competitive position within the domestic market, brought about by increasing scale economies of foreign production coupled with a moderate reduction of domestic trade barriers. For the most part, rationalization has involved the transition from an essentially branch plant industry to one which has become increasingly specialized within the context of a continental market.

Despite the fact that MES is large in relation to the size of the domestic television market, scale economies have not been a significant entry barrier in the industry. Until the mid 1970's domestic production insulated sub-optimal capacity in the industry from import competition. Thus, it has been possible to enter the Canadian electronic consumer product industries with plants whose capacities were a fraction of MES. Consequently the number of plants in the industry has borne little relationship to the optimum number set by the size of the domestic market and the smallest efficient unit of production. The resulting supply structure of the industry created the preconditions for the sector's rapid decline over the last decade and its apparent revival following extensive restructuring.

Until 1966 the Canadian Patent Pool effectively blocked the importation of televisions into Canada. This, along with the rapid growth of the domestic television market attracted a number of multinationals to the industry, establishing branch plants which produced exclusively for the domestic market. Operating behind a 15% tariff, domestic manufacturing enjoyed a period of relatively strong growth until a downturn in the domestic market in 1974. However, during this period the industry had become increasingly isolated from developments in the mainstream of television technology. Of particular importance were a number of technical advances in the manufacturing process which led to the development of larger production scales abroad[7]. Domestic producers did not respond to these developments primarily because the Canadian market could not sustain production volumes required for scale efficiency. Instead, the industry attracted additional sub-optimal capacity as three Japanese multinationals Hitachi, Sony and Matsushita, built branch plants in the early 1970's in order to circumvent the tariff[8].

The incidence of sub-optimal capacity in the Canadian television industry seems widespread as indicated by the following comparisons. Estimates of MES in television manufacturing range from annual production runs of 300,000 sets (DITC; 1978) to 500,000 sets (Charles Rivers Associates; 1978[9]). The largest Canadian plant by the mid 1970's had a capacity of roughly 100,000 sets and plant capacity in the industry averaged only 50,000 sets[10]. Thus a typical Canadian plant operated at between 1/6 to 1/10 the capacity associated with scale efficiency.

Without knowledge of the shape of the industry's long-run average cost curve it is difficult to determine the severity of cost disadvantages borne by sub-MES Canadian plants. Scherer et al. (1975) found unit costs 5-6% higher in plants 1/3 MES producing refrigerators and other household applicances with similar assembly type production[11]. However, anecdotal evidence, such as the inability of the tariff and severe price-cutting by domestic firms to arrest the pace of import penetration, suggests that Canadian plants may have incurred costs more than 15% higher than those of foreign scale efficient plants. Faced with cost disadvantages of this magnitude and widespread industry losses, many multinationals considered closing their domestic facilities and supplying their Canadian markets from foreign plants. In an effort to abate a mass exodus of foreign-owned firms and stabilize falling production and employment levels, the federal government undertook a number of initiatives in the direction of rationalizing the industry.

Efforts to redress the underlying scale problem in the industry draws attention to its degree of foreign ownership. By 1976 as many as 10 firms manufactured television sets in Canada, of which only one, Electrohome was Canadian owned. The remaining 9 firms were all subidiaries of multinationals and did not have mandates to produce for markets other than in Canada. Hence any move toward rationalization would involve commitments from multinational firms to retain and restructure their production facilities in Canada.

A rationalized industry, based on a domestic market of approximately 1.4 million sets, would hypothetically have contained a maximum of 3 to 5 MES plants, depending on which estimate of scale efficiency is used. Market fragmentation prevented any single manufacturer from commanding a large enough share of the domestic market to warrant an efficiently sized plant. In view of this constraint, the Department of Industry, Trade and Commerce encouraged the creation of a joint production facility between two or more producers and/or the establishment of a large scale facility by at least one multinational from which it could supply its North American market.

Both proposals failed to elicit industry support. The first plan was rejected because American owned firms feared that a move of this nature might violate U.S. anti-trust legislation. The second proposal was also rejected by U.S. based firms because the American industry was already rationalized with sufficient excess capacity to supply the much smaller Canadian market. Only Japanese multinationals were potentially willing to locate continental scale plants in Canada.

However, the imposition of American quotas on Japanese television imports compelled these firms to locate the bulk of their North American production in the United States. The construction of a 450,000 set capacity plant in California by Sony (1974), a 600,000 set capacity plant in Illinois by Matsushita (1974), a 700,000 set capacity plant in Arkansas by Sanyo (1977) and a 200,000 set capacity plant by Hitachi in Tennessee (1978) precluded the location of similar size plants in Canada[12].

Following these attempts at rationalization at the industry level, the focus of industrial policy shifted to the reorganization of production in individual plants. This policy was pursued through the Duty Remission Program introduced in 1977. The program called for the remission of duty on imported television sets until 1981 at which time tariff reductions would be implemented, The level of remission available to individual firms would depend on the degree of restructuring undertaken. In cases where the continuation of television production was no longer feasible, remission could be used to finance the cost of adjusting to other product lines or industry sub-sectors.

The program was designed to improve productivity by encouraging the greater specialization of Canadian plants. Duty remission would allow multinationals to import models previously assembled in their Canadian branch plants. In doing so, it enabled these plants to concentrate production in a narrower range of television models, thereby achieving cost efficiencies through economies of longer production runs. The excess of production above domestic requirements would be exported to the United States, thus facilitating some measure of North-South rationalization.

The industry's response to the Duty Remission Program is outlined in Table 11. Since the enactment of the program five foreign-owned firms including Philips, Quasar, Fleetwood, General Electric and recently, Canadian Admiral, have ceased television production in Canada. Canadian Admiral, which had originally intended to use the program to establish a plant to produce micro-wave ovens for the North American market, was sold by its American parent Rockwell International and has since been placed in receivership. RCA, Panasonic, Hitachi and Sony have reorganized production in their Canadian plants in a manner similar to that intended by the program. The single Canadian-owned manufacturer, Electrohome, has diversified into telecommunications through its involvement in the Telidon project and has concentrated the bulk of its television manufacturing in commercial television monitors.

The future of television manufacturing in Canada will depend largely on the degree to which the Duty Remission Program can promote productivity improvements through specialization. Although a thorough assessment of the program must ultimately await the impact of upcoming tariff reductions, there have been several noticeable, if not dramatic changes in the industry's recent performance. Productivity data for SIC 334 indicates a near trippling in Real Domestic Product per man-hour. Similarly exports, which rose sharply in 1976 due to the industry's anticipation of duty remission, quadrupled in 1977, and more than doubled in 1978. Despite a significant reduction in exports during the succeeding years, the 1980 level remained 20 times greater than the level established in 1975. The sudden emergence of an export capacity

Table 11

Industry Response to the Duty Remission Program

Canadian TV Producers	Owner	Response
RCA Canada	RCA (U.S.)	North-South rationalization of television production.
Electrohome	(Canadian)	Diversification into TV monitors and projection TV.
Canadian Admiral	Rockwell International (U.S.)	Plan to diversify into microwave ovens with Canadian plant supplying North American market*.
Philips	Philips (Dutch)	Ceased TV production in Canada.
Quasar	Matsushita (Japan)	Ceased TV production in Canada.
Canadian General Electric	G.E. (U.S.)	Ceased TV production in Canada.
Panasonic	Matsushita (Japan)	Plan to maintain employment levels.
Sanyo Canada	(joint Canada-Japan)	Plan to maintain employment levels.
Hitachi	Hitachi (Japan)	Plan to maintain employment levels.
Fleetwood	G.T.E. (U.S.)	Ceased TV production in Canada.

* Canadian Admiral has recently withdrawn from the industry.

Source: Electronics Industry - Sub-Sector Profile: Television Manufacturing, Electronics Task Force Secretariat, Department of Industry, Trade and Commerce, 1978.

seems closely related to the increased participation of foreign-owned subsidiaries in their parent firms' American markets. This is evident from the overwhelming percentage of industry exports shipped to the American market during the post 1977 period (Table 12).

Although televisions represent the vast majority of sub-sector output (accounting for between 75-80% of shipments) there are a number of other industries in this branch of the electronics sector. One of these industries, car radio manufacturing, has undergone structural changes similar in nature to those brought about by the Duty Remission Program.

Prior to 1965 the car radio industry consisted of a number of branch plants supplying a protected domestic auto market. However, in 1965 car radios sold original as auto equipment were included in the Canada-U.S. Auto Pact which eliminated tariffs on trans-border trade[13]. The dismantling of the domestic tariff wall prompted Philips, Motorola and several other multinationals to close their Canadian plants. These firms were largely replaced by affiliates of North American auto producers which established facilities to produce specific car radio models for both the Canadian and American market.

Although productivity estimates are not available (apart from those of the entire sub-sector), trade data suggests that the performance of car radio manufacturing compares favourably with that of non-rationalized segments of the sub-sector[14]. Between 1968-1975 the car radio industry was the only industry in the sub-sector which recorded a positive trade balance. Moreover, exports of car radios to the United States accounted for nearly 90% of all electronic consumer product exports despite representing no more than 10% of sub-sector shipments.

Table 12

Television Exports

Year	Total Exports Value (000's $)	Total Exports Quantity (number of sets)	Exports to the U.S. Value (000's $)	Exports to the U.S. Quantity (number of sets)
1970	4064	21739	3350	16739
1971	2498	17949	1743	11103
1972	836	5891	557	3767
1973	441	1988	199	633
1974	976	3184	158	761
1975	1429	4675	1081	3461
1976	4664	17361	4456	16860
1977	17128	80537	16530	79256
1978	42885	196826	41692	192763
1979	30057	92778	29432	90879
1980	28605	68250	24594	56961

Source: Statistics Canada, Catalogue 65-004

Computers and Other Electronic Office Equipment Sub-Sector (SIC 318)

SIC 318 is dominated by a group of American based multinationals engaged primarily in the manufacture of mainframe computers and related equipment. Many of these firms have evolved from suppliers of electro-mechanical office products and still produce some non-electronic goods such as electric typewriters[15]. However, the rapid growth in computer markets over the last two decades has lessened the importance of these goods to the extent that the vast majority of sub-sector shipments are currently electronic in nature.

Although most manufacturing in the sub-sector is related to mainframe computers, there are no facilities in Canada which produce entire machines. Instead, there are a number of plants which manufacture specific computer parts primarily for export. The emergence of more specialized plants oriented toward international markets follows widespread parent-subsidiary rationalization in the industry. This form of restructuring contrasts sharply with the branch plant mode of operation which prevailed in most of the industry's foreign-owned plants during the 1950's and early 1960's.

The structural transformation of the sub-sector has taken place within the context of broad technical changes associated with the transition from electro-mechanical office products to electronic computers.The manufacture of electro-mechanical office products was more suited to low volume production and the location of plants had been highly sensitive to domestic tariffs. These characteristics contributed to the frequent incidence of foreign-owned branch plants in the past. Alternatively, tariffs have played a relatively minor role in determining the location of computer manufacturing which has discouraged the establishment of assembly type plants in small protected domestic markets. In this latter case, government procurement and investment subsidies have been commonly employed in Canada and elsewhere to attract the location of scale efficient plants, producing largely for export markets. These industrial policy instruments, in conjunction with the trend among multinationals toward a greater global rationalization of computer production, have impacted the recent structure and performance of the sub-sector.

Industrial policy in this sector has been predicated on the assumption that there are insufficient domestic opportunities for the development of an indigenous mainframe manufacturer in Canada. This has led to the perception that future manufacturing in Canada will depend largely on the activities of foreign-owned subsidiaries. This viewpoint is supported by the presence of pronounced scale economies in the industry which, among other factors, has discouraged entry even in very large domestic markets such as the U.S. and has undermined the attempts of European governments to support the development of an indigenous industry. These considerations seem pertinent to the direction taken by Canadian industrial policy in this sector.

Despite the size of its domestic market, the American mainframe computer industry is very concentrated with four firms accounting for over 90% of the market (Table 13). Historically IBM has dominated the industry through its control of roughly two-thirds of the domestic mainframe market. In 1979 its market share rose slightly to 70.5%. By comparison, the next largest firm in the industry, Honeywell, had a 7.3% market share. Since 1965 no entrant to the industry has managed to capture more than a 1% market share and during this period a number of major electronic firms including Philco, RCA, General Electric and Xerox have left the industry.

Economies of firm size, product differentiation, and the leasing system have been identified as important determinants of the industry's structure[16]. Brock (1975) estimates that product differentiaition alone confers a 20-30%

price advantage to established firms. This estimate refers to the degree which a potential entrant must underprice established firms in order to induce users to switch brands. It is typical for a major manufacturer to re-supply as many as 80% of its original customers[17]. This apparent degree of product differentiation is largely explained by software 'lock-ins' which tie users to a particular manufacturer over successive generations of computer hardware. Lock-ins frequently result from a lack of compatibility between the software routines associated with specific brands of mainframe computers. Consequently users are discouraged from switching manufacturers by conversion costs which must be offset by savings in either price or lease rates[18]. This tends to protect the market share of large established firms and restrict the potential market available to newcomers.

Entry to the industry is further impeded by a number of scale economies which favour very large size firms. It is estimated that a firm with IBM's market share enjoys widespread cost advantages over its competitors which at most have only a tenth of its market. Scale economies result in 5-15 per cent lower units costs in manufacturing, 2-5 per cent in distribution, 15-20 per cent in maintenance and other support services and 50 per cent in software. A weighted average of these economies suggest an overall cost advantage of 19.4 per cent[19].

The most formidable barrier to entry is the industry's financial requirements. Estimates of the assets for the now defunct computer divisions of General Electric and RCA indicate that a minimum investment of approximately 1 billion dollars was needed for entry into the American industry during the early 1970's. If investment costs have kept pace with inflation it is likely that the level of minimum investment has since doubled.

Table 13

U.S. Market Shares of Mainframe Computer Manufacturers

(Percentages)

Firm	1955	1960	1965	1970	1975	1979
Amdahl	-	-	-	-	0.1	1.2
Burroughs	3.7	2.6	3.4	3.9	5.9	6.4
CDC	-	0.8	5.0	4.9	4.0	3.3
Bendix (1)	-	1.3	-	-	-	-
Digital Equipment	-	-	0.1	0.4	0.6	1.0
Honeywell	-	0.8	4.0	8.3	8.1	7.3
General Electric (2)	-	0.8	4.1	-	-	-
Xerox (3)	-	-	0.1	1.0	1.3	-
IBM	66.0	74.4	68.2	67.2	68.9	70.5
NCR	-	0.7	2.3	2.6	2.5	2.3
Philco	-	.4	0.8	0.3	0.1	-
Univac	19.4	12.3	8.5	7.2	7.9	7.2
RCA (4)	-	2.3	3.5	3.8	-	-

(1) Bendix sold its Computer Division to CDC, March 1963.

(2) General Electric's Computer Division was sold to Honeywell, October 1970.

(3) Honeywell acquired Xerox's installed base in 1976.

(4) RCA discontinued manufacturing computers in September 1971 and transferred its lease base to Univac.

Source: F. Kline, 1980, Computers: Key to Productivity in the Eighties, Drexel, Burham, Lambert Inc.

The magnitude of minimum investment levels is mainly attributed to the leasing system which, through the practices of IBM, has become an industry convention. An entrant must have financial resources at least ten times as great as its lease base in order to circumvent cash flow bottlenecks[20]. In addition, lease financing leads to initial negative rates of return by spreading revenue over the life of the rental term. All of these factors (in addition to others not dealt with here such as tactical price-curring by IBM) underlie the difficulties of entering the mainframe industry.

Despite the above implications, industrial policies in Europe have attempted to foster the development of their own indigenous mainframe industries. By and large these attempts have met with very limited success. The French firm, CII-HB, has managed to capture only 5 per cent of its domestic market despite having received roughly a quarter billion dollars of government support. Britain's national supplier, ICL, has maintained a somewhat greater share of its domestic market through public procurement but like its French counterpart has failed to compete effectively on international markets. West Germany has recently abandoned the objective of establishing a national supplier after earlier support to local firms failed to create an internationally competitive producer.

In Canada, reliance on foreign multinationals has focused government intervention in the computer industry on securing increased manufacturing for local subsidiaries. In doing so, industrial policy has emphasized the need for more specialized plants and broader market mandates for products produced in Canada. The extent to which government intervention has influenced parent-subsidiary rationalization is evident from the following summary of structural change in the industry over the last two decades.

Since 1966 multinationals have both closed and opened a number of plants in the industry. Considered separately, these changes have occurred sporadically and relate to specific corporate conditions. However, the cumulative impact of these changes have fundamentally altered the industrial landscape. Earlier branch plants, mainly producing electro-mechanical products, have either been scrapped or retooled for production of more specialized electronic products. New production facilities have been added, many of which export a sizable percentage of shipments to affiliated firms in foreign markets.

In most instances the location of new manufacturing facilities have been encouraged by government procurement and investment subsidies. One example of this type of intervention is the 8.3 million dollar PAIT grant given to National Cash Register for the construction of a plant in Waterloo which has a world product mandate for producing electronic banking equipment. The establishment of this plant enabled the firm to maintain a manufacturing presence in Canada following a decision to discontinue the production of electro-mechanical office products in a Toronto plant[21]. Other examples include a 20 million dollar PAIT grant to Control Data to establish a Canadian Development Division, a DREE grant (coupled with defense procurement) to Burroughs to set up a disc memory plant in Winnipeg and a federal purchasing agreement which encouraged Univac to build plants in Winnipeg and Dorval[22].

In other cases intense moral suasion has been used to induce industrial restructuring. This approach led to a specialization agreement between the federal government and IBM. Prior to the agreement the firm had largely been involved in assembly operations for the domestic market. The agreement brought about a restructuring of the Canadian subsidiary emphasizing product specialization and greater access to IBM's world markets. IBM World Trade Corporation granted the Canadian subsidiary partial world product mandates for key entry devices and electrical typewriters[23]. The large scale production of these products in Canada has led to the expansion of the firm's Toronto complex and the construction of a new plant in Bromont, Quebec. Between 1968-1976 manufacturing employment has grown by 35% and a five-fold increase in exports has enabled IBM to near its commitment for balanced trade between it and its Canadian subsidiary.

Digital Equipment is the only foreign-owned multinational in the sub-sector that has expanded the scope of its Canadian operations without direct government assistance or other forms of intervention. The firm produces computer back panels chiefly for export and assembles microcomputers for the domestic market. In addition, the company is involved in the development of electronic systems for application in Canadian resource industries.

Until very recently the participation of domestic firms in most areas of the sub-sector has been precluded by the size of scale economies in the computer industry. This has been tacitly recognized by government policy through its emphasis on efficiency as opposed to foreign control. However, current technological trends are introducing a new generation of electronic office products whose potential impact on industrial structure may rival the importance of earlier changes brought about by the obsolescence of most electro-mechanical office products. The advent of microprocessor based equipment including word processors and mini and micro computers are radically changing the composition of the market for electronic office automation equipment. These products are widely replacing traditional mainframe computers in many data processing applications and their share of the computer market is likely to increase significantly in the near future. To some extent this change in market composition has already occurred. In 1970 mainframe computers accounted for 94.7% of the world computer market. By 1980 its share of the market had fallen to 78% and is expected to drop to approximately 60% by 1985[24].

The rapid growth in the market for microprocessor type office equipment holds important industrial implications for Canada. The expected changes in the industry's product-mix will create greater opportunities for domestic firms. Unlike mainframe manufacturing, entry into these rapidly emerging markets is relatively open. As noted earlier in Chapter 1, scale economies are very minor, minimum investment is in the 5-10 million dollar range and like the case of other new electronic products, innovative producers can expect significant productivity growth through learning economies.

Already, a growing number of small indigneous firms have entered this end of the market. These firms are very technology intensive and their presence in the industry is usually predicated on a single product incorporating some novel technological attribute. Although market selection will likely weed out many of these enterprises, there are signs that some will survive and establish their own niche in the vast electronic office automation market. One Canadian firm, AES, has after a commercial life of only six years, become a major innovator in word processing equipment. The firm has gained international recognition as a producer of stand alone word processors (word processors which are sold as individual units but can communicate among themselves or with a mainframe system) and exports well over 75% of its output to world markets.

Recent structural changes which permit the emergence of firms like AES may lessen the industry's dependence on foreign-owned multinationals. The basic premise of past policy, the inability of small domestic firms to compete in a scale intensive industry, seems less appropriate with respect to the more dynamic segment of the computer market. Thus it may now be possible to increase the level of domestic control in the sub-sector without compromising the efficiency gains achieved through the past rationalization of foreign-owned subsidiaries operating in the mainframe arena.

Specialization and Intra-Industry Trade: A Test of the Rationalization Hypothesis

It has been frequently argued that as a result of specialization of firms within an industrial sector, both imports and exports of goods produced in that sector increase. Exports rise because specialization leads to larger production scales and lower unit costs, thus making those products in which the industry specializes more competitive on international markets. Imports rise because firms in the industry eliminate some product lines which they or others in the economy must then import.

In recent years the prospects for improved efficiency in Canadian manufacturing through trade induced specialization have been vigorously debated in discussions on industrial policy. Proponents of trade liberalization have argued that specialization is essentially an intra-sectoral phenomena. If so, the adjustment costs associated with structural change are likely to be less severe than the costs of relocating labour and physical assets across different industries.

Although instances of restructuring at the firm level are well known, it has been difficult to identify specialization at more aggregate levels. One approach is the Lermer test (1973) which attempts to measure the impact of structural change on the level of intra-industry trade[25]. It is argued that in the absence of specialization, increased demand for imports of a particular industry can be explained by changes in the level of national income. However, if specialization had occurred within the sector, a correlation should be found between movements in the volume of industry imports and exports. In this latter case, the inclusion of exports as an independent variable in an equation intended to explain import growth should improve the explanatory pwoer of the equation.

Although Lermer's inferences seem reasonable, the model does not control for other influences such as changes in the international terms of trade which may affect any functional relationship found between movements in industry exports and imports. Since the model cannot discriminate between endogenous and exogenous causation, its application is suspect in sectors where there is not prior evidence of rationalization. However, in the electronics sector there is evidence that specialization has led to the rationalization of large segments of the industry and this is reflected in sectoral trade flows. Therefore the results of the Lermer test may be interpreted as a partial confirmation or refutation of the rationalization hypothesis.

The Lermer test was used by fitting equation (1) by an ordinary least squares regression. The regression was run on industry trade data for the years 1970–1979.

$$(1) \quad I_s = a_0 + a_1 Y + a_2 X_s$$

I_s = imports of sector s

Y = GNP

X_s = exports of sector s

The expected values of the coefficients are as follows. In a rationalized industry, a_2 should be positive and significant, indicating a positive functional relationship between imports and exports of a common category of goods. Alternatively, in a non-rationalized industry the export coefficient would be insignificant and/or negative.

Separate regressions were run on individual sub-sectors and on an industry composite consisting of aggregated sub-sector data. The test at the aggregated industry level is designed to include specialization that may have escaped detection at the sub-sector level due to inter-sectoral restructuring. The results from these regressions are summarized in Table 14.

At the industry level rationalisation is confirmed by a positive and significant export coefficient. The income coefficient is also positive and significant. Rationalization was also confirmed in three of the five industry sub-sectors. In the case of components, the income coefficient was found to be insignificant which suggests that rationalization must have been relatively strong to account for import growth. However, in two other cases rationalization was not confirmed at the sub-sector level. The a_2 coefficient for the instruments and systems sub-sector was positive but not significant at the 95% level and the coefficient was significant but negative in the telecommunications sub-sector. The difficulty of obtaining accurate trade data for the instruments and systems sub-sector may have had some bearing on the sector's inconclusive results. It is likely that the perverse results in telecommunications indicate the impact of foreign governments' procurement policies on domestic investment decisions. In particular, the Rural Electrification Authority's domestic content regulations compelled Northern Telecom to supply an increasing percentage of its American market from its U.S. subsidiary instead of through exports of Canadian made products. Given the firm's importance in the sub-sector, it is reasonable to assume that Northern's response to American protectionism has influenced the relationship between sub-sector imports and exports.

Table 14

Regression Results

Sector	Y Coefficient	t Stat.	X Coefficient	t Stat.	R^2	D.W. Stat.
Total	.641238	3.76851**	1.68336	3.76851**	.9854	1.86
Components	.113853	1.18864	3.16535	2.65588**	.8812	1.4752
Telecomm.	.18947	17.4023**	-.195358	2.97725**	.9941	2.1589
Consumer Products	.19822	6.29493**	1.09626	1.74706*	.9581	2.1808
Computers & Instruments	.520520	3.69546**	1.79694	1.84098*	.9629	1.3525
Instruments	.810354	3.98460**	.299660	1.00724	.9595	1.7235

* significant at the 95% level, ** significant at the 99% level

Footnotes

1. H. Eastman and S. Stykolt, 1967, The Tariff and Competition in Canada (Toronto, MacMillian Press).

2. D. Daly, B. Keys and E. Spence, 1968, Scale and Specialization in Canadian Manufacturing (Ottawa, Economic Council of Canada); R. Caves, 1975, Diversification, Foreign Investment and Scale in North American Manufacturing Industries (Ottawa, Economic Council of Canada).

3. C. Green, 1980, Canadian Industrial Organization and Policy (Toronto, McGraw-Hill Ryerson).

4. R. Caves, 1975, Diversification, Foreign Investment and Scale in North American Manufacturing Industries (Ottawa, Economic Council of Canada).

5. Ibid.

6. H. English, 1964, Industrial Stucture in Canada's International Competitive Position (Montreal, Private Planning Association).

7. Production scales rose significantly during the late 1960's and early 1970's in Japanese and American plants. Changes in manufacturing techniques appear to be closely related to the introduction of integrated circuits and other microelectronic components in television receivers. For a summary of technological change in the television industry see Charles Rivers Associates, 1978, op cit.

8. Japanese Economic Journal 5/9/1972.

9. Electronics Task Force Secretariat, 1978, op cit., Charles Rivers Associates, 1978 op cit.

10. Electronics Task Force Secretariat, 1978 op cit.

11. F. Scherer, A. Beckenstein, E. Kaufer, R. Dennis and F. Bourgeon-Massen, 1975, The Economics of Multi-Plant Operations: An International Comparisons Study.(Cambridge, Mass., Harvard University Press).

12. Japanese Economic Journal 23/1/1979.

13. Car radios sold as replacement equipment were not covered by the agreement. Consequently entry into the sizable American replacement market is impeded by a 10% tariff.

14. The following tables provide a comparison of trade and production statistics between automobile radios, other consumer products (radios, tape recorders, record players) and televisions.

14. Continued...

Automobile Radios

(millions of constant 1971 dollars)

	1968	1975
Domestic Market	22	30
Shipments	39	31
Imports	5	22
Exports	22	23
Trade Balance	17	1

Other Consumer Products

(millions of constant 1971 dollars)

	1968	1976
Domestic Market	98	191
Shipments	63	46
Imports	41	147
Exports	6	2
Trade Balance	-35	-145

Television Receivers

(thousands of sets)

	1956	1976
Domestic Market	622	1423
Shipments	614	471
Exports	0	92
Imports	8	1044
Trade Balance	-8	-952

The comparison illustrates a fundamental difference between protected industries and the car radio industry. In the former case exports are negligible and import growth have significantly reduced domestic production. However, in the latter case exports have more or less stabilized domestic production levels despite the increase in the level of import penetration. Source: Electronics Task Force Secretariat, 1978 op cit.; Electronics Task Force Secretariat, 1978, Electronics Industry Sub-Sector Profile: Radio and Other Consumer Electronics Products (Ottawa, Department of Industry, Trade and Commerce).

15. For example, the largest firm in the sub-sector, IBM, controls approximately 80% of the domestic market for electrical typewriters in addition to its estimated 55% share of the Canadian mainframe computer market.

16. G. Brock, 1975, The U.S. Computer Industry(Cambridge, Ballinger Press).

17. A study of purchasing habits by mainframe users in the U.S. revealed that 91% of Burrough's customers remained with the manufacturer in updating their system. Similar levels of consumer allegiance were found among IBM customers (82%), Honeywell (79%) and NCR (76%). Cited in G. Brock, 1975, op cit.

18. Conversion costs vary dpending on the extent to which programs and data formats must be changed. Frequently conversion requires the retraining of operators and programmers who may not be familiar with a new system. Secondly, each manufacturer offers its own dialect of high level computer languages in order to optimize specific machine characteristics. Therefore, even if different manufacturers' computer languages are compatible there is likely to be a loss in software efficiency if programs are used onmachines with different operating characteristics. Thirdly, if programs are not compatible, a major investment in programming must be made in order to accommodate the software requirements of a new operating system. In the extreme case, a user's data may not be in a format that is acceptable to a different manufacturer's machine. The conversion costs associated with converting large volumes of data into another format are generally prohibitive regardless of any price or rental savings which might result from switching manufacturers.

19. G. Brock, 1975, op cit.

20. G. Brock, 1975, op cit.

21. Electronics Task Force Secretariat, 1978, Electronics Industry Sub-Sector Profile: Computers and Office Products (Ottawa, Department of Industry, Trade and Commerce).

22. Ibid.

23. The Canadian firm along with one other subsidiary of IBM are the only two locations outside of the United States which produce electric typewriters. Source: Ibid.

24. F. Kline, 1980, op cit.

25. G. Lermer, 1973, Evidence from Trade Data Regarding the Rationalizing of Canadian Industry, Canadian Journal of Economics, (6) 2.

CHAPTER 3

TRADE POLICY

The rapid growth in the level of intra-industry trade has been a key feature of the recent development of the Canadian electronics industry. Although it has led to a mounting trade deficit in most electronic products, trade has provided a major impetus for the rationalization of large segments of the industry. The continuation of these trends will at least in part depend upon the course of future sectoral trade policy.

The primary concern of government in determining trade policy is the maximization of net social benefits for its citizens. This objective may or may not be consistent with a trade surplus. In this respect policies must be assessed from the perspective of their potential contribution to increasing social welfare. Thus an optimal policy is one which achieves the greatest social gain regardless of its impact on the balance of trade.

Theoretical Arguments for Protection

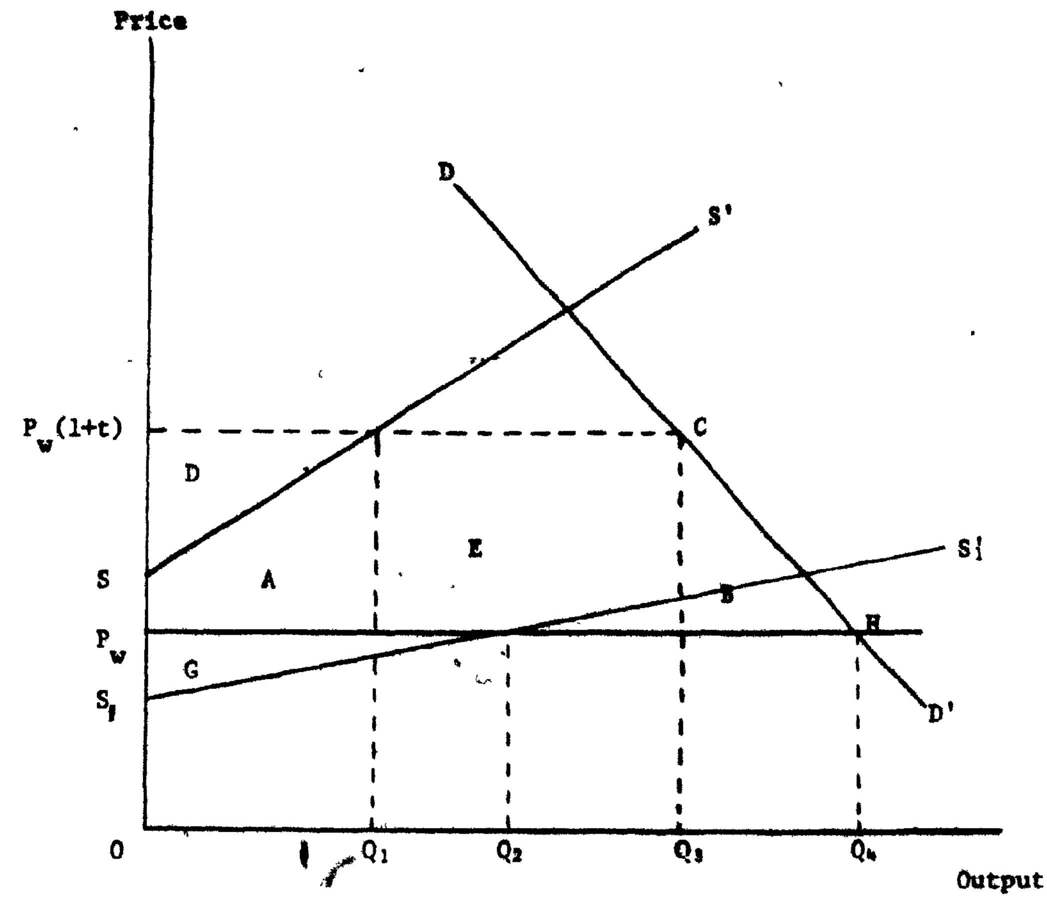
Standard neoclassical theory maintains that protection will generally lower social welfare by inducing an inward shift in the economy's consumption possibility frontier. In addition to reducing the real income of consumers, tariffs encourage an inefficient allocation of resources. There are however, two rationales within the framework of neoclassical analysis for governments to deviate from a free trade policy. The terms of trade and infant industry arguments provide cases where the protection of a domestic industry will result in a national social welfare gain.

The terms of trade refer to the price ratio between a country's imports and exports. An improvement in a nation's terms of trade can be brought about by a decrease in the relative price of its imports. If a country's consumption of an imported good is sufficiently large to influence the world price, it can lower that price by restricting domestic demand through a tariff. The reduction in the world price of the imported good will improve the nation's terms of trade at the expense of exporting countries. At some optimal tariff rate the terms of trade effect will outweigh the efficiency loss associated with the tariff induced divergence between domestic and world prices. Provided that the importing country has sufficient market power to influence world demand, protection can lead to a social welfare gain[1]. Nevertheless, it is important to stress that the terms of trade argument is predicated on the use of market power and for this reason is not generally applicable for small economies which cannot affect world prices by changing their level of domestic consumption.

The infant industry argument can be applied more readily to small economies since it does not rely on the use of market power. It is instead based on the assumption that a potential comparative advantage could be realized if an emerging domestic industry is temporarily protected from import competition. It is argued that infant industries cannot initially withstand import competition, but, given temporary protection, they can in time, become internationally competitive. It is possible that, taking into account the future efficiency improvements in the industry, the present value of the welfare effects of protection will be positive.

The potential welfare gains from infant industry protection are illustrated in Figure B. In the case shown it is assumed that the home country is sufficiently small that it takes the world price of the commodity as a given. Thus, the supply curve of imports is horizontal at the world price P_w. It is further assumed that there is an increasing cost domestic industry whose supply curve is upward sloping.

DIAGRAM B



Under free trade P_w is the domestic as well as world price for some good . Given a domestic demand curve DD', the home market will consume OQ_4 units of the product, all of which are imports. If a protective tariff is applied at an ad valorem rate t, the domestic price will become $P_w(1+t)$. At the new equilibrium point (C), domestic consumption falls to OQ_3. OQ_1 units of the good will be produced by the domestic industry while the balance (OQ_3-OQ_1) is supplied through imports. Consumer surplus falls, relative to its free trade level, by the sum of areas D,A,E, and B. However, the tariff creates a producer surplus equal to area D since price exceeds the marginal cost of domestic producers up to OQ_1 . In addition, government revenue increases by area E which is equal to the level of imports times the tariff rate. On balance there is a net welfare loss of A+B per period. Now suppose that the domestic industry learns 'by doing' to produce more efficiently and the domestic supply curve shifts downward to S_1S_1' from its original SS' position[2]. To simplify, we can depict an essentially continuous process in discrete terms. Imagine that this shift occurs suddenly at the end of period X after which the tariff is removed. The domestic price is restored to its original free trade level but the domestic industry has increased production to OQ_2. The gain from protection is given by area G which is the producer surplus earned on domestic production following the removal of the tariff[3]. The present valye of the costs and benefits induced by the tariff can be calculated as follows.

$$P.V. = \left[\frac{G}{(1+r)^{X+1}} + \ldots \frac{G}{(1+r)^{n}} \right] - \left[A+B + \frac{A+B}{(1+r)^{m+1}} + \ldots \frac{A+B}{(1+r)^{X}} \right]$$

where r = social discount rate

m = period in which the tariff is implemented

n = number of periods following the removal of the tariff

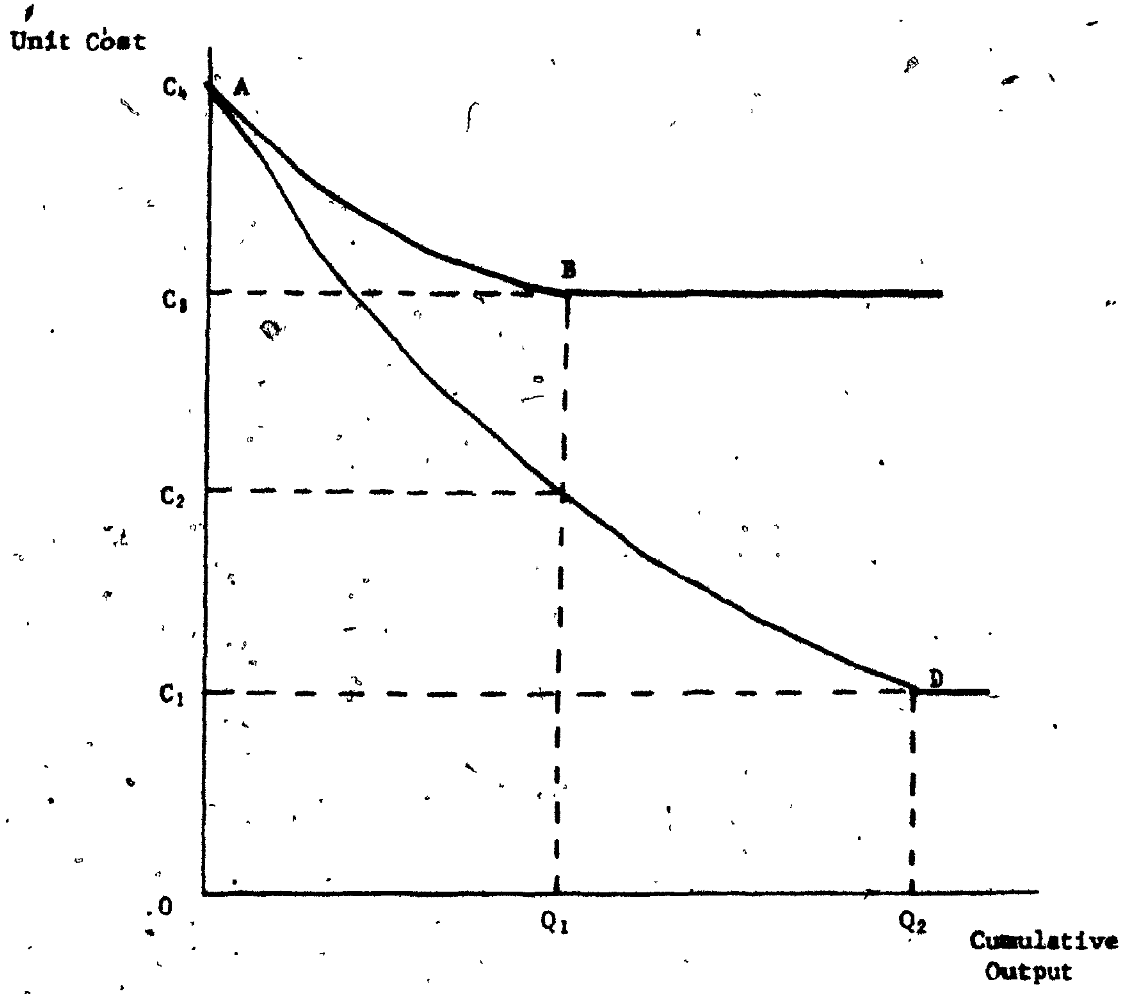
If the above expression yields a positive present value, infant industry protection will lead to a net gain in social welfare relative to free trade.

Externalities associated with unrealized scale economies are suggested by the infant industry argument[4]. The presumption is that the industry can actually realize these economies through a protected domestic market. Hence the size of the protected market relative to the level of MES is crucial. If the size of the market is not large enough to sustain scale efficiency there is no reason to believe that protection will succeed in lowering production costs to the point where the infant industry will ever become internationally competitive.

Economies of scale can be present either in the conventional sense of economies associated with the rate of output per time or in the more dynamic sense of economies associated with cumulative output over time. The latter variety of scale economies are better suited to the infant industry argument since they involve inter-temporal changes in efficiency[5]. In the case of learning economies, the validity of infant industry protection depends on the rate of learning and the range of cumulative output in which learning takes place[6]. This information is given by the slope and the asymptote of the learning curve. If learning occurs indefinitely it is inappropriate as an argument for infant industry protection since mature competitors will always operate at lower unit costs than later entrants. On the other hand, learning may subside beyond some level of cumulative output in which case an infant industry could become internationally competitive provided that sales in the protected domestic market permit it to reach the asymptote of the curve.

The importance of the parameters of the learning curve with respect to protection is shown in Figure C.

DIAGRAM C



The curves AB and AD denote two possible loci of a learning function. The first curve reaches an asymptote at B where producers attain a long-run minimum average cost of OC_3 with OQ_1 units of cumulative output. The second curve, AD, is more steeply sloped and unit costs continue to decline to OC_1 with increasing cumulative output up to OQ_2. Relative to a fully mature firm, the cost disadvantage encountered by entrants operating along curve AB is $OC_4 - OC_3$ and the disadvantage for those operating along curve AD is $OC_4 - OC_1$. If domestic cumulative demand during the period under consideration equals OQ_1, the protected infant industry can capture all learning economies along curve AB but not along curve AD. On curve AB the domestic industry will have achieved cost parity with more mature foreign competitors since differences in cumulative output beyond OQ_1 have no bearing on their relative competitiveness. However, in the latter case, the cost reduction achieved through learning economies up to OQ_1 will still leave domestic producers lagging behind the efficiency of foreign firms with greater levels of cumulative output.

There is yet another argument for protection which complements, but is not necessarily dependent on, the infant industry case. Preferences in public procurement for domestically produced goods represent a major barrier to trade in certain industries. They are particularly evident in electronics and other high technology industries where public procurement is a relatively important source of demand. In interviews, several electronic system firms suggested that procurement policy performs a signalling role by conveying information about the quality of unproven products to potential customers in foreign markets and to a lesser extent to those in the private domestic sector. The rationale for signalling intervention through public procurement policy is that potential foreign customers will perceive a product to be inferior if the home government of the manufacturer does not fulfill its own requirements with the locally produced good. This, in effect, would constitute negative signalling and hinder the acceptance of the domestically produced product in foreign markets.

The signalling argument is typically applied to innovative capital goods where the user is particularly concerned with the performance, safety and reliability of the product. For example, the procurement of advanced electronic devices for defense and aerospace applications is generally based on these types of considerations rather than solely on cost. In these markets, past reputations for reliability confers a major advantage to established firms over lesser known but not necessarily less reliable competitors. This form of product discrimination poses severe entry barriers to new firms, particularly if they are native to countries which do not have large markets for their products. In these circumstances, prior procurement by the firm's home government may create demonstration effects which enhance the firm's international credibility and mitigate the barriers they face in foreign markets.

The need for signalling intervention is paramount in cases where market discrimination in foreign countries is not warranted by the user's rational appraisal of the risk associated with the product. For example, arbitrary purchasing conventions which require the demonstration of past performance may unduly discriminate against the acquisition of a lesser known or more recent, but superior product. In this case the arbitrary purchasing convention would have adversely affected market selection. On the other hand, procurement conventions may reflect the market's rational evaluation of the risk involved with an unproven product or unknown manufacturer. The question then becomes whether the home government of the producer should be willing to assume a sizable risk either through the direct procurement of the product or through posting a performance bond on behalf of the manufacturer in sales to the domestic private sector or to customers in foreign markets. This ultimately depends on the ability of the government to absorb risk more efficiently than the private sector. If the government holds such an advantage, the use of public procurement as a signalling device may be justified even in the absence of a market failure. (The matter of the state's risk bearing advantage will be discussed more thoroughly in the following chapter on R and D policy).

Although the signalling argument provides a rationale for governments to support domestic manufacturers through public procurement, it does not imply that governments should only purchase from domestic suppliers. It must be stressed that signalling phenomena are not present in all product markets but only in specific cases where there is extreme danger from a malfunction. Thus, unlike the terms of trade and infant industry arguments, it cannot be applied universally to all industries. Furthermore, where signalling phenomena are present, the argument does not justify the acquisition of a domestically produced good if it is actually inferior to an imported substitute.

Trade Policy for the Canadian Electronics Industry

The level of domestic consumption in any of the product sub-sectors of the industry is insufficient to provide leverage over world prices. Thus, in the absence of market power, there is no reason to believe that protection of the domestic industry would improve Canada's terms of trade in electronic products. If protection is warranted, it must be in terms of an infant industry argument.

The infant industry argument has been shown to depend critically on the relationship between scale efficiency and the size of the protected domestic market. Our data on static scale economies in the industry indicates that MES is very large relative to the size of the Canadian market. MES is extremely high in semiconductors and mainframe computers, less so but still substantial in the manufacture of electronic consumer products, and moderately high in word processors, mini-computers and most telecommunication equipment.

There is less conclusive evidence regarding the relationship between dynamic scale economies and market size. Learning is pervasive throughout most sectors of the industry with real unit costs typically falling 20-30 per cent with every doubling in cumulative output. A lack of quantitative information concerning the shape of learning curves in the industry does not permit us to determine to what extent these economies could be realized in the domestic market. However, there is qualitative evidence, based on interviews with firms in the learning intensive telecommunication, computer and system sub-sectors, that realization of these economies require access to international markets. This viewpoint was corroborated by the fact that exports accounted for 60-80 per cent of these firms' sales.

Although one cannot dismiss the possibility that there may be some areas of production where dynamic scale economies could be captured within the home market, such cases have not been evident. Moreover, data on static scale economies suggests that the Canadian market is too small to justify infant industry protection. In fact, the earlier reported finding on increased specialization in the industry suggests that many Canadian firms are already internationally competitive and are expanding their sales to foreign markets.

Trade liberalization, particularly with the United States, is also implied by the technological nature of comparative advantage in electronic goods. Both the incidence of innovation and the rate of imitation of new technology seem to be strongly correlated with market size[7]. These findings are consistent with the product life cycle theory which maintains that economies of scale in R and D, access to specialized demand, and the availability of a large pool of highly skilled labour favour the development of new technology in industrialized nations with large domestic markets[8]. This suggests that access to the vast U.S. electronics market would provide greater commercial opportunities for Canadian inventions and thus stimulate the technological performance of the industry.

Trade liberalization throughout the industry is suggested by the inapplicability of the standard arguments for protection and by dynamic considerations regarding the technological competitiveness of the industry. However, differences in the relative competitiveness of sub-sectors, the level of foreign protection in potential sub-sector export markets, and in the degree of sectorial interdependence suggest that liberalization might be best undertaken through a sub-sector approach. In some sub-sectors there is scope for immediate unilaterial action whereas in others multilateral action (or at least bilateral trade liberalization agreements between Canada and the United States) would be preferable. Therefore it is useful to consider trade options within the context of the individual sub-sectors of the industry.

Telecommunications

The Canadian telecommunications sector is highly competitive internationally. Exports currently account for one-third of sub-sector shipments and represent over half of the sales of the sector's major firms. Since domestic producers are already competitive both at home and abroad, free trade could facilitate an expansion of the industry through increased exports. The potential benefits from free trade are reinforced by the fact that the domestic market is relatively small in comparison to currently protected foreign markets.

In principle, multilateral agreements to reduce all tariffs on telecommunication equipment would be ideal from a Canadian standpoint. There are however, a number of deeply embedded non-tariff barriers in Japan and in most European telecommuniction markets which would minimize the impact of tariff reductions. It is commonplace in these markets for publicly owned phone utilities to be either formally or informally linked to domestic suppliers of telecommunication equipment through procurement arrangements. A variety of technical standards requiring the customization of equipment for specific national markets has effectively blocked import penetration into those countries[9].

There are no such impediments to trade between Canada and the United States since equipment produced in either country is compatible with each other's telecommunication systems. Nevertheless, there have been other barriers which have limited Canadian exports to the American market. The most important trade barrier facing Canadian firms has been the procurement link between AT&T controlled phone utilities and its manufacturing subsidiary, Western Electric. The possible dissolution of these links, following a recent agreement between AT&T and the American Justice Department, creates potentially enormous export opportunities for Canadian firms such as Northern Telecom[10]. These opportunities would be enhanced through a bilateral elimination of all tariffs on telecommunication products between Canada and the United States.

Components

Not only is an infant industry argument inappropriate for components, but protection in this sub-sector undermines the competitiveness of electronic end-product manufacturers who rely heavily on imported semiconductors as intermediate inputs. By reducing the cost of these inputs, the elimination of duties on imported components would be beneficial to producers in all other sub-sectors and particularly to those firms which produce final goods for export. For this reason even a unilateral abolition of tariffs would be preferable to maintaining the current 5-15 per cent tariff rates on component imports.

Computers

Canadian tariffs on computer equipment range from 10 to 20 per cent. In view of the scale economies in the industry, it is highly unlikely that Canada will ever be able to support indigenous manufacturers of mainframe computers. The modest level of current manufacturing is done almost exclusively by subsidiaries of foreign-owned multinationals. Aside from some remaining assembly operations geared toward the domestic market, production by foreign-owned subsidiaries has been largely rationalized for the international markets of their parent firms Consequently the removal of tariffs on computer imports is unlikely to jeopardize their future presence in Canada. Moreover, a removal of the tariff would have a positive impact on the competitiveness of a number of other industries which use computer equipment as intermediate inputs. The tariff poses a particular burden for data processing firms whose overall costs are raised by 5 per cent by the duties on computer hardware[11]. This burden is exacerbated by the fact that domestic data processing firms compete with U.S. firms in a number of regional markets in both Canada and the United States[12]. The situation is therefore similar to components and calls for a unilateral abolition of the tariff.

Consumer Products

Canada's competitive position in electronic consumer products is undermined by the scale and labour intensity of the industry. In recent years there has been a growing trend among North American producers toward offshore assembly despite protection of consumer product industries in both Canada and the United States. It is probable that the locus of comparative advantage will continue to shift to less developed countries with cheaper unskilled labour.

Our analysis of rationalization in the sub-sector suggests the possibility of a North American infant industry strategy. This would entail sectoral free trade between Canada and the U.S. in televisions, radios and other electronic consumer products but protection from imports of third countries. The level of foreign ownership in the sub-sector implies that sectoral free trade should be accompanied by specialization agreements requiring the intra-firm rationalization of American multinationals currently operating in Canada. This could conceivably lead to the location of scale efficient plants in Canada producing specialized products for an aggregated continental market. However, it is unclear whether scale efficiency would be sufficient to restore the sector's competitiveness given the comparatively high cost of unskilled labour in Canada.

Electronic Systems

Canada's trade prospects in electronic systems are mixed. Although Canada has considerable potential at the sub-system level, domestic firms lack the necessary corporate depth to compete effectively in markets for large system products.

The domestic market for electronic system products is extremely small due to the very specialized nature of these products. For this reason virtually all electronic system firms in Canada are export oriented. System sales to foreign markets are rarely affected by tariffs, but non-tariff barriers, usually in the form of domestic content regulations are commonly encountered. These barriers are frequently circumvented through local sourcing of intermediate inputs.

The presence of signalling phenomena in international system sales suggests that there is latitude for public intervention through procurement policy. Public procurement of domestically produced electronic systems may generate signalling effects which positively influence the foreign procurement of these products.

Notwithstanding such effects, it is widely known that other countries pursue similar policies. When all countries purchase from their own domestic suppliers the impact of signalling on market selection is partially negated to the extent that foreign public sector markets become effectively closed to imports.

Non-Tariff Barriers

The incidence of non-tariff protection in electronics has constituted a major source of friction in international trade. The Canadian industry, which is highly dependent on trade due to the small size of its home market, is placed at a greater disadvantage in a world of covert protection than other industries whose much larger domestic markets lessens the importance of access to foreign demand. Thus, in negotiating sectoral trade liberalization, Canada should seek comprehensive agreements with its trading partners which entail the reduction, if not elimination, of both tariff and non-tariff barriers. Failure to secure reductions in non-tariff barriers would seriously undermine the effectiveness of a policy toward trade liberalization.

Footnotes

1. There is however, the possibility that trading partners may retaliate by levying optimum tariffs on goods in which they have market power. The end result can be that both countries are worse off than initially, but it is theoretically possible that one country may possess sufficient market power to enable it to impose a tariff that leaves it better off even after retaliation.

2. An increasing cost industry does not preclude the possibility that producers may realize dynamic scale economies. For example, costs may increase because input prices are bid up with increasing output. When the industry supply curve shifts downward, the price of inputs continue to rise with their greater usage but the industry's marginal cost at a given level of output is lower relative to previous periods due to learning induced productivity gains.

3. Area G denotes a producer surplus since the industry supply curve rests below the world price to the left of OQ_2. The fact that the industry supply curve rests below the world price does not necessarily imply that the domestic industry's production costs are lower than in the rest of the world. If imports are subject to higher transportation costs than domestic output, it is conceivable that domestic production costs are higher than foreign producers but that domestically produced goods are sold at a lower price in the home market due to lower transportation costs.

4. Grubel treats this as an externality which arises from the fact that the benefits of eventual cost reductions associated with future scale efficiency cannot be entirely internalized within the protected industry. Domestic users of the output of the protected industry benefit from price reductions which follow from the realization of scale economies in the domestic market. For example, suppose that there are economies of scale in the production of integrated circuits. If the domestic market for integrated circuits increased, the domestic price of integrated circuits would fall as greater efficiencies in production are achieved through larger scale economies. However, individual users of integrated circuits cannot anticipate that their actions alone will induce a price reduction - even though collectively they could achieve this result. Therefore while there is no incentive for an individual user to increase demand for circuits, a concerted increase by all domestic users of integrated circuits would be socially optimal for the user industries as a whole. The tariff would induce this type of collective behaviour and therefore confer external benefits to user industries. For a discussion of this and other externalities associated with infant industry protection see H. Grubel, 1977, International Economics, pp. 160-163 (Homewood, Irwin).

5. If there are static scale economies the industry could become competitive without the aid of tariff protection by simply investing in efficient size plants. However, if efficiency is derived from learning over time there may be need for a period of temporary insulation from import competition.

6. Another relevant factor is the price elasticity of domestic demand. If demand is price inelastic, price reductions will have a minimal impact on the growth of the domestic market and will limit the industry's cumulative output to some level less than that otherwise obtainable with a more elastic demand.

7. J. Tilton, 1971 op. cit.

8. For a discussion of the product cycle theory of trade see L. Wells, 1972, The Product Life Cycle and International Trade (Boston, Harvard University Press).

9. Electronics Task Force Secretariat, 1978, Electronics Sub-sector Profile: Telecommunications (Ottawa, Department of Industry, Trade and Commerce).

10. In order to retain control over Western Electric, AT&T has recently agreed to divest itself from ownership in local telephone exchanges. Whether this will alter the procurement policies of local utilities is as yet unknown, but it is at least plausible to argue that this development will potentially open up significant segments of the U.S. telecommunication equipment market to Canadian exports.

11. This finding was obtained through interviews with firms in the data processing industry.

12. Currently there are no barriers on the trans-border flow of data between Canada and the United States. This has enabled regional competition between Canadian and U.S. data processing firms. For example, firms in Southern Ontario can service clients in Northeastern American states and vice versa. Similarly, California based firms compete with domestic data processing firms in markets in Western Canada.

CHAPTER 4

R AND D POLICY

In most countries the bulk of overt government support for the electronics industry has been channeled through R and D subsidies. It is widely felt that massive subsidization of R and D in the industry is essential in order to maintain the technological competitiveness of domestic producers. This view is accompanied by a vague notion that future industrial success hinges on an increased domestic capacity in the area of microelectronic technology and that the private sector will not on its own allocate sufficient resources to the development of this technology.

Seldom if ever have the economics of public support for R and D in electronics been demonstrated. While support programs have dwelled at length on the future potential of this sector, the crucial issue of market failure remains an implicit yet unsubstantiated assumption. There may of course be the standard problems of inappropriability, learning and other economies of scale, and risk bearing which call for public intervention but these considerations do not seem to figure much in discussions of subsidy policy nor do they appear to justify the amount of support given by governments to electronics. It instead appears that spiralling levels of support follow from a political perception held among governments of producing nations that they must not lag behind others in supporting their native industry.

What follows is an attempt to focus on some of the more salient economic issues underlying public policy toward industrial R and D. There are three fundamental questions concerning policy which require economic analysis. The basic question is will the private sector, without government intervention, allocate the socially optimal level of resources to R and D. The answer is indeed fundamental to the very basis of subsidization since in the absence of market failure, intervention cannot be justified on the grounds of allocative efficiency.

Assuming that there is a market failure, the next question is the appropriate response by the state. The efficacy of intervention will depend largely on the manner in which it impacts corporate behaviour. For example, if subsidies are selected as the instrument for intervention, it must be shown that they do not simply displace privately funded R&D expenditure. Lastly, there is the issue of determining the optimal size of a subsidy (or other form of support) in order to maximize potential social gains from any given R & D project.

The Basis for Public Intervention

There are two theoretical arguments for public support of R and D. Both arguments suggest reasons why the market will not allocate the socially optimal level of resources to R and D. The first argument concerns the imperfect private appropriability of the returns to R and D while the second focuses on the uncertainty of those returns.

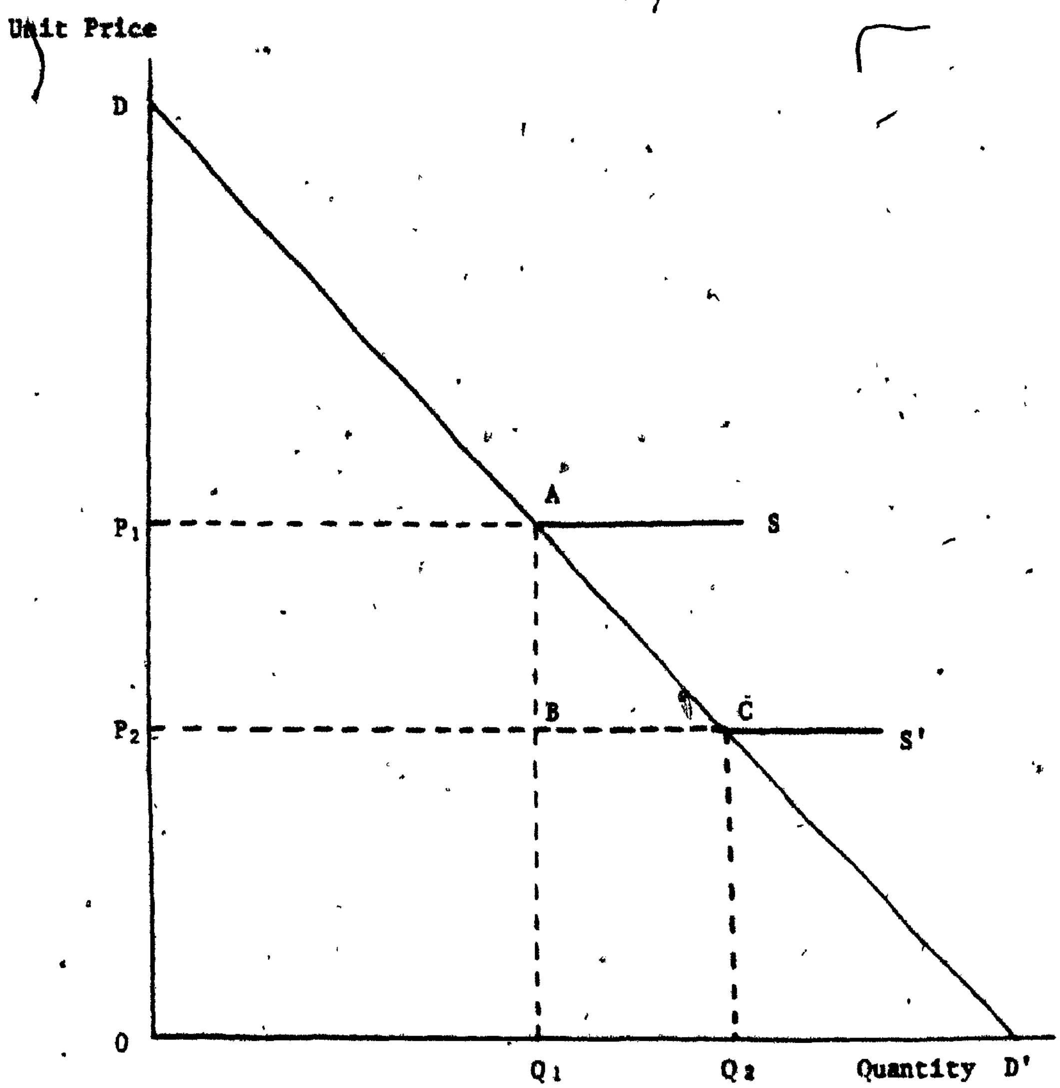
Inappropriability and Public Intervention

An invention may be regarded as the production of information. Information is essentially a public good since those who do not contribute to it cannot be excluded from acquiring it. Furthermore, as Arrow notes, the marginal cost of distributing an additional unit of information (that is making the innovation available to an additional user) is effectively zero[1]. In order to guarantee the optimal utilization of the invention no royalties should be charged for its use. But if the price of acquiring new information is zero, as Arrow's observation implies, investors will be unable to appropriate any private return from inventions and the market will fail to allocate any resources to inventive activity.

The traditional remedy for the inappropriability problem is the patent system which is intended to stimulate private investment in R and D by permitting inventors to earn monopoly profits from their inventions. However, Nordhaus (1969) and McFetridge (1977) have shown that patent rights can never induce the market to allocate additional resources to R and D without simultaneously reducing the social return on the deployment of those resources[2]. For this reason the market cannot produce information as efficiently as the state if the state conducted all R and D and made any resulting innovations available at no cost. Short of this idealized system, there is scope for improving social welfare through the payment of R and D subsidies which induce a greater allocation or resources to innovative activity by the private sector. Subsidies are warranted under a finite patent term because the social benefits from a cost reducing invention can never by entirely appropriated by the owners of the invention. Thus, in the absence of subsidies, the profit maximizing level of investment in R and D will be less than the socially optimal level .

The case for subsidy intervention can be demonstrated through the following example of a process innovation. If there is perfect certainty concerning the outcome of R and D investments, a given allocation of resources to innovative activity can be expected to result in an innovation which reduces the cost of producing good X. If producers of good X can acquire the invention at no cost, its adoption in a competitive industry will lower unit prices from OP_1 to OP_2 and lead to a concomitant expansion in industry output from OQ_1 to OQ_2. This is shown in Figure D by the invention induced downward shift in the industry supply curve from P_1S to P_2S' . The social welfare gain obtained from the use of the invention is given by the area P_1ACP_2. Part of this gain, P_1ABP_2, is the reduction in the value

DIAGRAM D



of resources required to produce the original output (OQ_1) and the balance, ABC, is the consumer surplus derived from the additional output (OQ_2-OQ_1).

A social rate of return on the resources allocated to the invention (R and D expenditure) can be calculated from the flow of social benefits per period (P_1ACP_2). If the rate of return is at least as great as the social discount rate the allocation of resources to the invention will be Pareto efficient. It should be noted however, that in the absence of patents this investment would not have been undertaken by the private sector. The private rate of return on the investment is zero since no part of the social gain from the invention can be appropriated by the owners of the resources allocated to the invention. In other words, the increase in productivity brought about by the innovation is exhausted in the price decrease so that no economic profits are earned by either the inventor or the users of the invention. Consequently, the invention could only have been undertaken by the state.

Alternatively, the private rate of return on R and D investments can be protected through a patent. Consider the extreme case where the inventor may claim an indefinite property right over the innovation and restrict its use through a royalty charge. For 'run of the mill' inventions which involve relatively small cost reductions, the maximum royalty rate per unit of output that can be extracted by the inventor from producers of good X is equal to the cost reduction achieved through the use of the invention[3]. In this case the adoption of the invention will leave the price and level of output of good X unchanged. Nevertheless, there is still a social gain from the invention since it facilitates a more efficient production of OQ_1 units of X. This gain, P_1ABP_2, is the royalty income which accrues to the inventor and falls short of the maximum social gain by an amount equal to the forgone consumer surplus (ABC).

Realized social gains approach, but never equal maximum gains (P_1ACP_2 per period) as either the royalty rate or the patent term approach zero. A lower royalty rate implies that the innovation will induce some price reduction in a competitive industry but as long as the royalty rate is positive, the industry supply curve will rest above P_2S'. Similarly, the social benefit from the invention can be increased by shortening the duration of the patent term since the full social benefits per period are obtained upon the expiration of the patent. A patent term of shorter duration increases the number of periods where the social benefits are at a maximum and thereby raises the aggregate social benefits that are realized over the commercial lifetime of the innovation. However, any patent term greater than zero will reduce social benefits by the present value of the lost consumer surplus while the patent is in effect.

The preceeding analysis reveals the fundamental contradiction inherent in the patent system: The owners of an invention can only profit from it if output is restricted and price raised above cost. Patents induce the market to allocate a greater level of resources to investments in innovative activity but do so at the expense of limiting the social benefits that are obtained from those investments. Furthermore, a patent of finite duration can never fully resolve the inappropriability problem since the social rate of return on an invention will always exceed the private rate of return due to the implicit consumer surplus which is not privately appropriable. Therefore the rate of cost reduction which maximizes earnings for the owners of R and D resources will remain less than the rate of cost reduction which maximizes social benefits[4].

McFetridge notes that the divirgence between the socially optimal rate of cost reduction and the profit maximizing rate can be eliminated through the payment of a subsidy to private investors. The size of the subsidy will depend on the extent of the divirgence between the flow of social and privately appropriable benefits from any given cost reducing invention. Since privately appropriable benefits increase relative to social benefits with the length of the patent term, the value of the subsidy will decrease as the patent term increases. Thus for process innovations, the subsidy will be zero if there is an infinite patent term since all social benefits are privately captured. Conversely, the value of the subsidy will increase due to the rising consumer surplus as the patent term approaches zero. When the patent term is zero none of the social benefits can be appropriated privately and the subsidy will equal the full R and D cost. This latter case is tantamount to the state conducting the R and D itself and making the innovation available at no cost. Although the social benefits produced by any patent-subsidy combination (except a zero patent term and a full subsidy) can never equal those produced by state conducted R and D, subsidies can nevertheless facilitate an improvement in allocative efficiency.

Attempts have been made to show that under certain conditions state intervention may not necessarily bring about a more efficient allocation of resources to R and D. Eads (1974), for example, argued that in oligopolistic industries with non-price competition or in situations in which government regulations affect the allocation of resources to inventive activity, subsidies may induce an overallocation of resources to R and D[5]. McFetridge has drawn attention to a special case where the social benefits from an invention with private ownership and a patent of unlimited duration equal the maximum benefits obtained through the public ownership of the invention. If the inventor has the ability to discriminate perfectly in the pricing of good X the full social benefits may be appropriated privately. In such a case the inventor could monopolize production of good X by operating along a demand curve P_1AD and thereby earn P_1ACP_2 per period. This gain includes ABC which is otherwise the consumer surplus that is not privately appropriable. Perfect price discrimination yields the maximum social gains and therefore is equivalent in efficiency terms to state conducted R and D. However, under perfect price discrimination all of the social gains accrue to the owner of the R and D resources and accordingly is less desirable than state ownership from a distribution standpoint.

McFetridge's analysis is essentially concerned with process innovations. However, cost reducing innovations may also take the form of new final products. If a product innovation performs a function similar to that of existing products, the analysis of inappropriability is identical with that of a process innovation. For example, in Figure D, S can be regarded as the supply curve of a conventional good and S', the supply curve of its substitute, the innovative good. This analogy will be valid for most product innovations since they normally represent an improvement over existing goods.

In rare cases, an innovation may lead to the production of an entirely new good for which there is no existing substitute (i.e. the discovery of the photocopying machine). When the new product fulfills a unique function the entire area underneath the demand curve must be considered as a consumer surplus. Except for the special condition of perfect price discrimination, the development of a wholly new product will always result in a consumer surplus regardless of the length of the patent term. This point can be demonstrated in Figure D by assuming that a new product is sold at a unit price of OP_1 and is produced at a unit cost of OP. In the case of a process or substitute product innovation the entire social gain would be appropriated by the monopoly profits (P_1ABP_2) which accrue to the inventor. An inappropriability problem would arise only if the patent term is finite. However, for innovations which result in wholly new products, a consumer surplus equal to DP_1A occurs even with a producers surplus of P_1ABP_2. Thus the inventor is unable to fully appropriate the social gain even with a patent term of infinite duration.

A final consideration in the analysis of inappropriability is the possibility that the commercialization of a product or process innovation may require the inventor to make capital expenditures in new plant and equipment. Unlike the actual R&D expenditure, these costs may not necessarily be assumed in the supply curve shown in Figure D. In such circumstances an inventor might reap gross earnings of P_1ABP_2 per period but could incur negative earnings once investment costs are considered. By the same token, investment in new plant and equipment must be considered in the calculation of net social benefits.

In cases where the commercial development of an invention requires a substantial capital expenditure in new plant and equipment, the necessary condition for a social gain is that the present value of the consumer and producer surplus must exceed the investment cost (K). In our previous example of a product innovation the following must hold.

$$\frac{DP_1A}{r} + \frac{P_1ABP}{r} > K$$

The condition for subsidization based on inappropriability is that the social gain (consumer plus producer surplus) exceeds the investment cost and that the latter exceeds the producer surplus. Thus:

$$\frac{DP_1A}{r} + \frac{P_1ABP_2}{r} > K > \frac{P_1ABP_2}{r}$$

In summary, a Pareto efficient allocation of resources to R&D in a competitive market with perfect certainty can be achieved either by the state conducting R & D or by private individuals with the ability to perfectly discriminate in the pricing of the invention. An efficient market allocation of resources will also occur in the case of a process or substitute product innovation if the inventor is granted an infinite patent term. If the life of patents are finite, or if perfect price discrimination is not possible, the market's allocation of resources to R&D will be socially suboptimal. In these circumstances a more efficient allocation of resources can be effected by the payment of a subsidy, owing to the imperfect private appropriability of the returns to R&D.

Risk Bearing Intervention

Up to this point we have abstracted from the problem of risk by assuming perfect certainty. The introduction of uncertainty and risk averse behaviour adds an important dimension to the issue of public support for innovative activity. A fundamental result obtained from the consideration of risk is that investors will always choose to hold an asset with the least risk from a selection of assets which share a common rate of return. This simply reflects the fact that risk is an economic cost which risk averse individuals will attempt to minimize.

Once risk is allowed to influence investment decisions, subsidization may no longer be sufficent to induce a Pareto efficient allocation of resources to R and D. For example, projects with potentially high social rates of return may not be undertaken by the private sector if they are considered too risky, even with partial subsidization. This raises the question of whether the state should be prepared to invest in these projects in order to maximize social welfare. The solution to this problem rests with the state's ability to bear risk at a lower cost than the market.

Arrow (1962) and Arrow and Lind (1970)[6] have argued in favour of the state assuming a risk bearing role. In both cases, the argument is predicated on the law of large numbers which require certain assumptions concerning the probability distribution of the outcome of individual investment projects. Given the appropriate assumptions, it is maintained that the state may ignore the risk associated with any given project and finance all projects where the social rate of return exceeds the social discount rate.

The first variant of the case for the state to assume a risk bearing role is the pooling argument advanced by Arrow. This is essentially the standard theory of portfolio selection which maintains that the variance of the expected rate of return on a portfolio of assets whose outcomes are statistically independent from each other approaches zero as the number of assets held increases. By pooling the risk across a very large number of projects , the risk associated with an investment in any single project will have a negligible effect on the average return to the portfolio. Arrow contends that in this fashion the state can effectively eliminate risk whereas a private investor, holding a far less diversified portfolio, cannot.

The extent to which pooling can eliminate risk is limited if there is a partial correlation between the outcomes of separate projects. If the rates of return on individual projects are partially correlated, risk pooling can reduce but not entirely eliminate risk regardless of the size of the portfolio.

A second, although related argument for state intervention is the concept of risk spreading. Risk spreading involves the distribution of the risk of a single project among a very large number of investors whereas the former argument concerns the pooling of risk across many projects in order to reduce the variance on the aggregate rate of return to zero. Arrow and Lind argue that the state holds an important advantage over the private sector since it can spread the risk of any given project across all taxpayers such that the risk borne by each individual taxpayer is insignificant.

> "when the risks associated with a public investment are publicly borne, the total cost of risk bearing is insignificant and therefore the government should ignore uncertainty in evaluating public investment. This result is obtained not because the government is able to pool risk but

> because the government distributes the risk associated with any investments among a large number of people. It is the risk spreading aspect of government investment that is essential to the result" [7].

In so far as they are statistically possible, the risk pooling and/or spreading argument has been challenged on the grounds that it fails to demonstrate why the state is better equipped to perform these functions than the market. McFetridge argues that if pooling reduced or eliminates risk there is no reason why a market institution would not emerge and perform this function by assuming an equity position in a large number of projects. Through such an institution the private sector could finance socially desirable projects which might otherwise be too risky for a single investor or firm to support.

> "Risk reduction is an economic good for which risk averse individuals would be willing to pay. One would therefore expect to observe the emergence of an institution which, operating through the market, supplied this good. If for example, the return to all R and D projects are independent, an institution which has an equity position in a large number of projects, each of which was in excess of the (risk-free) social discount rate, would consistently earn a rate of return in excess of the discount rate. That is, the variance on the rate of return to the institution would approach zero. Such an institution would find ~~it~~ profitable to take an equity position in any R and D project with an expected rate of return in excess of the risk-free discount rate, regardless of the variance of the distribution of its possible rates of return". [8]

McFetridge attributes the absence of such institutions in the marketplace to moral hazard problems and transaction costs, each of which may reduce the expected rate of return below the risk-free social discount rate. For example, moral hazards may follow from the institution's absorption of the risk since this effectively divorces innovators from some of the costs and benefits associated with the outcome of their inventions.

Diminishing incentives for those directly involved in the inventive process may adversely affect the expected rate of return on the resources allocated to R and D. In addition, the risk-pooling institution may incur transaction costs associated with the continual monitoring and evaluation of the projects which it has taken an equity position in. These costs may not be trivial, and again could reduce the expected rate of return to a point where the investment would no longer be attractive.

McFetridge maintains that the state is no less susceptible to the factors which militate against the emergence of a market institution. Unless the state can avoid moral hazard problems or operate with lower transaction costs, it is in no better position to bear risk than the market. McFetridge concludes that since it has yet to be shown that the state has an inherent advantage in dealing with these problems, there is no justification for it to support projects which the private sector will not support on account of risk considerations.

Although there is no real basis for challenging McFetridge's contention with regard to moral hazards, there is reason to question his pessimism concerning the ability of the state to operate with lower transaction costs than a market institution. It is possible that, given the state's existing activities and institutional infrastructure, it may achieve lower incremental administrative costs in risk pooling and/or spreading. For example, the state may realize economies of scope, in effect joint production, by allocating the responsibility for monitoring and evaluating projects among agencies such as the Departments of Industry, Trade and Commerce, Finance and Science and Technology which have already been established to perform similar tasks. Although this remains an unsettled issue, it is at least plausible to argue that risk bearing intervention is justified on the basis of lower transaction costs for the state.

Policy Implications for the Level and Type of State Support For R and D

The appropriate level of state support for R and D projects depends chiefly on whether intervention is justified solely on the basis of private inappropriability of the returns to R and D or whether it is also based on the state assuming a risk bearing role. McFetridge proposes the following guidelines for subsidy support which is based solely on considerations of imperfect appropriability. McFetridge's model is predicated on three earlier stated assumptions; 1) the rate of cost reduction in a given industry is a positive function of the resources allocated to R and D in that industry, 2) social benefits are positively related to the rate of cost reduction, and 3) there is a finite patent term on any invention which results from R and D investments. Given these assumptions it is possible to determine the socially optimal subsidy for either an investment in a single R and D project or for a continuous stream of R and D investments. Let us first consider the discrete case of an individual R and D project. McFetridge's rule for determining the socially optimal subsidy is given in equation 1.

(1) $g' - G' \geq u \leq B' - G'$

where u = the present value of the optimal subsidy given for a specific R and D project

g'= the present value of the R and D cost of the project

G'= the present value of gross private benefit from the project

B'= the present value of the gross social benefit from the project

Equation 1 states that the government should subsidize the difference between the project's costs and private benefits up to a maximum set by the difference between gross social benefits and gross private benefits (G'-g'). With respect to Diagram D, the maximum subsidy is limited to the difference between P_1ACP_2 and P_1ABP_2 . This rule implies three conditions for subsidization. The first condition is that the gross social benefits from the project exceed gross private benefits ($B' > G'$). In the previous example this requires that $P_1 ACP_2 > P_1ABP_2$. If $G' > B'$, there is no appropriability problem and thus no basis for the payment of a subsidy. In cases where subsidization is warranted, the second condition is that the size of the subsidy should not exceed the difference between the project's cost and the gross private benefits ($u \leq g'-G'$). This confines the earnings on the resources allocated to R and D to their opportunity cost. Finally, the subsidy should not exceed the difference between gross social benefits and gross private benefits ($u \leq B'-G'$ or in Figure D, $u \leq ABC$). If the subsidy exceeds this limit it would induce an overallocation of resources to the R and D project which would have the effect of reducing national income. The income loss would be equal to the difference between the cost of the project and the social benefits resulting from it.

The same principles can be applied to the case where the rate of cost reduction is a continuous function of the resources allocated to R and D. However, in this instance we are concerned with marginal conditions. When applied to the continuous case, u is the optimal marginal subsidy or the present value of the subsidy payment in terms of dollars per unit of cost reduction, g', is the present value of the R and D cost of an additional unit of cost reduction, G' is the marginal private benefit or the present value of an additional unit of income which accrues to the producer from an additional unit of cost reduction, and B' is the present value of the marginal social benefit arising from an additional unit of cost reduction. Other than maximizing social benefits at the margin instead of on a per project basis, the rules for subsidization remain the same.

The McFetridge framework, in effect, rules out the subsidization of projects which the market will not take on because of risk considerations. It has been suggested however, that the state may be able to operate at a lower discount rate than the market and support riskier projects. The inclusion of risk bearing intervention does not in itself alter McFetridge's subsidy guidelines but it is likely to affect the type and level of suppprt government may provide.

Inappropriability and uncertainty are distinctly separate problems which evoke different policy responses. In response to uncertainty, the risk bearing argument suggests that the state assume an equity position (or provide loans) in the projects it supports whereas the inappropriability problem calls for direct subsidization. Thus the issue is not simply the level of support but the <u>type</u> of support which is required in each case. Since both factors are typically present, a mix of support instruments is called for. Government may provide subsidies so that the expected private rate of return on a socially desirable project is positive. In addition, the state may act an an investor and assume an equity position in the same project to aid the firm in bearing risk. Although this will not affect the size of the subsidy given to any one project, it is likely to increase the number of projects undertaken in the private sector and thus enlarge the pool of projects which may become eligible for subsidization. In this manner state investment will indirectly raise the aggregate level of subsidies given in support of private sector R and D.

Foreign Ownership and Public Subsidies

A question of particular relevance to the Canadian electronics industry is whether or not the government in granting subsidies should distinguish between foreign-owned and domestically owned firms. McFetridge makes the compelling argument that although the social benefit under domestic ownership is greater than under foreign ownership, the marginal social benefit resulting from the payment of a subsidy is the same regardless of the nationality of the recipient.

Where the rights to the innovation are domestically owned, the social benefit from a cost reducing innovation is the sum of the private benefit plus the increase in consumer surplus. However, if the private benefit accrues to foreigners it can no longer be considered part of the social gain from the invention. It is instead a cost which reduces the social benefit since foreigners have a claim on domestic goods and services equal to the size of the private benefit. Thus the social benefit resulting from an innovation will always be greater if the rights to the invention are domestically owned.

The same however, does not hold for the marginal social benefit created by a subsidy. The value of the subsidy is the opportunity cost of the additional resources allocated to R and D for the realization of the privately inappropriable consumer surplus. Since none of the increase in social benefits created by the subsidy accrues to the owners of the R and D resources, their nationality is of no consequence. Therefore on the margin there are no grounds for discriminating between foreign-owned and domestically owned firms.

There are however, grounds for scrutinizing the subsidy requests of foreign-owned firms more thoroughly since any subsidy payment in excess of the opportunity cost of the additional R and D resources is a cost which reduces net social benefits in Canada. This does not apply for domestic firms although a payment above the opportunity cost would be undesirable from a distribution standpoint. The need for greater scrutiny of the subsidy requests from foreign-owned firms is reinforced by a number of empirical observations which suggest that although they spend less on R and D in Canada than domestically owned firms, there is a greater probability that they will both apply for and receive a subsidy[9].

Evidence on the Social and Private Rates of Return to R and D

A central assumption underlying the previous discussion on subsidy policy is that the social rate of return from R and D exceeds the private rate of return. This assumption is supported by a number of studies in the U.S. which indicate that the social rates of return from R and D are very high compared to the private rate of return on both R and D and other privately held assets. Although no estimates of this sort have been made in Canada there is no a priori reason to assume they would differ significantly from those made in the United States. Therefore a brief summary of the American findings seems appropriate.

Mansfield et al. (1977) calculated social and private returns on 17 industrial product and process innovations by U.S. companies. The authors found that the average estimated social rate of return was about 56 per cent which they consider a lower bound. This compares favourably with Griliches (1958) finding that the internal social rate of return from the development of hybrid corn was 37 per cent. The private rate of return varied widely among innovations but the average, 25 per cent, was substantially below the social rate of return. The authors point out that in 30 per cent of the cases the private rate of return was so low that with hindsight no firm would have undertaken the investment whereas the social rate of return from the innovation was so high that from society's viewpoint this investment was well worthwhile. Mansfield and associates attribute the difference between the social and private rates of return to problems of appropriability. Thus, they find that the difference is largest for the more important innovations for which the compulsion to imitate is the greatest and for those imitations that can be imitated most cheaply by competitors.

Elsewhere Mansfield et al. elaborates on these findings. According to their estimates and less elaborate ones made by others such as Minasian (1969) and Terleckyj (1974) on the rate of return to R and D, it can be argued that there is an underinvestment in civilian technology. Although this may be interpreted as a call for greater government support for R and D and innovative activity, the authors are uncertain about the effectiveness of such intervention. Our findings and those of McFetridge, Porter and Hewitt provide some empirical basis for Mansfield's pessimism regarding the impact of greater support on private R and D expenditures.

Of particular interest to this study is an attempt to estimate the social benefits from innovation in the electronics industry. Wilson, Ashton and Egan (1980) estimate consumer surplus associated with the development of MOS (metal-oxide silicon) dynamic RAM (random access memory) chips in the United States between 1971 and 1978. They assume no change in quality, no shifts in demand, and no significant income effects all of which allows them to interpret the annual sales of producers as points on the industry's demand curve. They calculate a very large consumer surplus, $300-500 million, which they consider a conservative estimate. Although no attempt is made to distinguish between social and private rates of return, the authors suggest that most gains went to consumers since competition was intense during this period. In this respect the results are consistent with those of Mansfield et al. and others.

The Determinants of Innovative Activity

Although there are conceptual and measurement problems associated with innovative activity, there is a general consensus that the incidence of innovation is positively related to R and D expenditure (Terleckyj 1974, Mansfield 1977, and Griliches 1954, 1980). On the basis of these findings it seems reasonable to use R and D expenditures as a proxy for innovative effort and to focus on the determinants of those expenditures.

Most studies of the determinants of R and D expenditure or R and D intensity (expenditure/sales) have considered firm size, market concentration, government subsidies and ownership (foreign vs. domestic) as explanatory variables. We will consider some of the general findings regarding firm size and market concentration and then consider studies on all four variables including our own which use Canadian data.

There are reasons to support varying viewpoints on the nature of an innovatively optimal market structure. Among those factors which favour larger firms are the risk associated with innovative activity, economies of scale in R and D, and better access to product markets. It may be argued that large firms face lower risks in innovation through greater diversification and are therefore more willing to undertake innovative activity than smaller firms . They may also be able to conduct research at lower cost since there may be economies of scale associated with existing R and D facilities. Lastly, larger firms with market power may have important advantages in marketing new products and thus are more adept at commercializing innovations.

On the other hand, small firms are often more flexible and responsive to the potential of an innovation than large firms. It may also be true that in small firms the relationship between the marketing and research staff is less encumbered by bureaucracy which, according to Mansfield et al (1977) increase the probability that an innovation will become a profitable new process or product. Similarly, Wilson, Ashton and Egan (1980) found that size was often an impediment to innovative activity in the semiconductor industry because size and inflexibility seemed to go together. These sentiments are also shared by Tilton (1972) who has stressed the importance of a competitive market structure in the rapid rate of innovation in the

U.S. semiconductor industry.

Turning to the empirical work, there is little support for the Schumpertarian hypothesis that R and D intensity increases monotonically with either firm size or market concentration. It seems instead that both innovational effort and output increases with firm size up to a certain point and then remains constant or decreases as firm size increases (Howe and McFetridge 1976, Kamien and Schwartz 1975).

Kamien and Schwartz have found that the relationship between innovative effort or output and market concentration is no stronger than its relationship to firm size. They suggest that R and D is nonlinearly related to industry concentration. This viewpoint is also held by Scherer who envisions an optimal market structure consisting of a mix of small firms which would supply the new ideas, a core of medium sized firms to develop these ideas into marketable processes or products and a few large firms to take on mega projects. This implies that, at least in the U.S., a market structure midway between monopoly and perfect competition would generate the highest rate of innovative activity. Although it is difficult to draw more concrete inferences from the empicial evidence, it seems safe to conclude that a policy which promoted monopolies or tight oligopolies would be unlikely to increase innovative effort and output.

It is however legitimate to question whether an innovatively optimal market structure would differ in Canada from that in the United States. For example, Scherer's conception of a medium sized firm in the U.S. context is roughly equivalent to Northern Telecom, by far the largest electronics firm in Canada. Similarly, small firms in Canada are by U.S. standards, minute if not microscopic. Although there is no clear cut answer to this question, it can be argued that in relatively small countries such as Canada, the government would have to assume a larger role than it would in the United States for the so-called mega projects. An example of this in the electronics industry may be the role which the Canadian government has assumed in the development of Telidon.

Another factor commonly investigated as a determinant of innovative activity is ownership. It is widely held that, in the process of global rationalization, multinationals centralize R&D functions in the laboratories of the parent firm. Accordingy, one might expect foreign-ownership to have a negative influence on the level of a subsidiary's R&D expenditure. This hypothesis has been widely confirmed in a number of regression tests which measure the impact of foreign ownership on R&D expenditures with all other relevant variables held constant.

There are two implicit behavioural assumptions which underlie empirical investigations into the influence of foreign ownership on R&D expenditures. The first assumption is that a foreign-owned subsidiary's R&D effort can be measured by the amount that it itself spends on R&D. This effectively precludes the possibility that a subsidiary might have its parent firm conduct R&D work on its behalf. If this were the case the subsidiary's own level of R&D spending would not accurately reflect the full extent of its R&D involvement and the regression coefficient would be negatively biased.

A second and perhaps more serious assumption concerns the causal link between a subsidiary's R&D effort and its technological performance. It is normally assumed that the fruits of innovative activity are reaped by those who perform this activity. Thus there is concern that if foreign-owned subsidiaries do not engage in R&D they are unlikely to gain the opportunity to produce innovative products and thus contribute to the economic growth of the host country. However, the presumption that the manufacturing activities of a foreign-owned subsidiary are related to its R&D effort is subject to an increasing amount of controversy. For example, Cordell argues that many multinationals organize R&D on the basis of an interdependent network of international laboratores which are linked together by functional tasks. The R&D work leading to a new product may typically be spread across a number of international laboratories, each working on a specific section of the project. Moreover, the type of R&D projects undertaken by a subsidiary may not be at all related to the type of products which it manufactures. This will often be the case when the R&D department is administratively autonomous from the local management of the subsidiary and reports directly to the parent firm.

An outstanding example of this type of organizational behaviour within a multinational is cited by Cordell with respect to IBM's development of its 7722 audio response unit in the early 1970's.

> "To illustrate, let me cite the history of the IBM 7722 audio response unit which is used in voice answer back applications. The original idea came from our Zurich Research Laboratory, feasibility was proven in our German Development Laboratory. The actual product was developed in our French Laboratory and the end product is now manufactured in our Kingston, New York plant. The programming support for this machine had to be included in an overall programming package developed in our British laboratory".
>
> (Mr. Papo, Director of Standard, IBM World Trade Corporation, Research Management, Jan., 1971, pp. 19).[10]

The relative ease by which technology can be transferred within a multinational firm, and the integrated nature of its R&D establishments, casts doubt on the traditional linkage between a subsidiary's R&D effort and its technological performance. The fact that some or all of the R&D work for an innovative good is conducted in one location does not necessarily imply that once developed, the product will be manufactured in the same location. Conversely, efforts to secure a greater R&D presence by foreign-owned subsidiaries in Canada does not guarantee that resulting innovations will be manufactured here. In view of these considerations it may be provisionally suggested that government concerns over the technological performance of foreign-owned subsidiaries might be best addressed through negotiations with multinationals over product mandates for Canadian plants as opposed to policies which focus on increasing R&D expenditure per se.

<u>Evidence on the Effectiveness of Government Support of R and D in Canadian Industry</u>

Econometric studies on the effect of government support on R and D expenditures in Canadian industry have been undertaken by Howe and McFetridge (1976), Porter (1980), and Hewitt (1980). A common finding is that the sensitivity of private R and D expenditures to public grants varies significantly across different industries.

Howe and McFetridge, examining the electrical goods, chemical and machinery sectors, find that with the other relevant determinants of R and D held constant, the value of government grants received by firms had a significantly positive influence on the amount of self-financed R and D undertaken. This result was obtained from a regression analysis which calculated the elasticity of firms' R and D expenditures (net of subsidies) with respect to government grants. An elasticity greater than one implies that the receipient of a grant increased its self-financed R and D expenditure by an amount greater than the subsidy. If this elasticity is greater than zero, but less than one the subsidy will have the effect of increasing privately financed R and D outlays by an amount less than the subsidy. The subsidy will have no effect on the level of privately financed R and D expenditures if the elasticity is zero while a negative elasticity indicates that public grants displace private funding. However, as long as the value of the elasticity of firms' R and D expenditures with respect to subsidies is greater than -1 the subsidy will increase the total value of resources allocated to R and D.

Since the value of the subsidy coefficient was never found to be significantly less than zero, Howe and McFetridge conclude that:

> "the incentive grants are not simply displacing private funds. Our results imply that, at the very least, the subsidies have the effect of increasing by the amount of the subsidy the value of resources allocated by society to R and D".[11]

The estimated elasticities varied significantly across sectors and in one case between dometically owned and foreign-owned firms. For example, the elasticity was found to be greater than one among domestically owned firms in the electrical goods sector. The elasticity was less than one but greater than zero for foreign-owned firms in this sector. The coefficient of R and D incentives in the chemical and machinery sectors could not be shown to be significantly different than zero. Thus the results indicate that the stimulative effects of subsidies on R and D expenditures varies significantly between different industries.

Porter's study is of particular interest because, unlike other studies reported here, some of his regressions embody an attempt to control for variations in technological opportunitv across industries. This is done by examinine for each of 84 three dieit Canadian industries the difference between R and D intensity (R and D/sales) in the Canadian industry and that in its matched American counterpart industry. In those regressions which do control for technological opportunity, he finds that the variable capturing the percentage of R and D outlays financed by government is a significantly negative influence on the R and D intensity of the industry. Porter concludes that either the Canadian subsidy actually discourages R and D in industries where it is high relative to U.S. industries, or in these circumstances it is acting as a proxy for a poor domestic industrial environment that is not completely captured in the model.

Hewitt links the effectiveness of government subsidy programs to the behavioural responses of individual firms. He postulates two polar type of responses to government grants. On one extreme are firms which are either generally unaware of available programs or are so confused about eligibility requirements that they completely ignore the possibility of receiving a grant. These firms, when given grants, treat them as windfall gains and are referred to as 'radical windfallers'. Since these firms draw up their R and D budgets on the assumption that they will receive no government support there should be no significant relationship between the percentage of their R and D outlays financed by government and the level of R and D undertaken. At the other extreme are firms which are so intimately acquainted with government grant programs that they consciously adjust their R and D activities to take maximum advantage of these grants. In the case of 'perfect responders' there is likely to be a very strong positive relationship between government support and the firm's own R and D expenditure.

Hewitt's analysis suggests that there is a market failure which arises from imperfect information concerning grant programs. Firms which have greater access to information on grants are better able to make use of them than less informed firms. There may also be learning economies in the process of applying for grants which would reinforce Hewitt's contention that there are differences in responder behaviour. If these economies are present, firms with the most cumulative experience in dealing with government R and D subsidy programs are likely to be the most successful grant applications, notwithstanding objective considerations of worthiness. Learning economies in grant applications may also be industry specific, in which case those industries which have the greatest experience in soliciting R and D grants will command an advantage in obtaining subsidies. In fact, Hewitt's empirical results are consistent with this interpretation.

Hewitt's empirical work investigates the determinants of R and D in the same three 2 digit sectors covered in the Howe and McFetridge study as well as one three digit industry,communication equipment (SIC 335). It should be noted that SIC 335 encompasses the telecommunication and components sub-sectors of the electronics industry. This SIC is included in the electrical goods sector in both the Hewitt and Howe and McFetridge study but is also examined separately by Hewitt. Hewitt finds that the level of government support was a significantly positive influence on R and D in the electrical goods sector and in SIC 335 (responder behaviour), although the rate of increase in R and D diminished as the level of support increased. Subsidies were ineffective in stimulating R and D in the chemical and machinery sectors.

Hewitt suggests that in order to minimize future radical windfall behaviour and thus improve the effectiveness of government subsidies, granting agencies should attempt to keep eligibility requirements straightforward and to change those requirements as infrequently as possible. It is tentatively suggested that unconditional tax relief (tax credits) may be a more effective instrument for stimulating R and D than grant programs. This follows from the perception that the potential stimulative effects of such programs are dampened by the fact that all firms do not possess adequate information about them. However, it should be noted that tax credits are not readily applicable to a case by case approach. It has been earlier demonstrated that the size of the appropriate subsidy and/or loan or equity investment will depend on the expected costs, benefits, inappropriability and risks of each prospective project. It is difficult to see how these criteria can be maintained if support is based on a standard tax credit which is applied universally to all privately financed R and D expenditures.

The Determinants of R&D Spending in the Telecommunications and Components Sub-Sectors

Using data compiled by an Economic Council of Canada survey of innovative behaviour among firms classified in SIC 335, a regression analysis was undertaken of the determinants of the level of firms' R&D outlays[12]. The data, consisting of a sample of 57 firms, permitted testing for the following explanatory variables; total sales of the firms in 1978 (SALET78), the square of total sales (SAIESQ), a dummy variable equalling one for foreign-owned firms and zero otherwise (FORGNOWN), the percentage of funds spent on R&D (for the innovations reported by the firm in the ECC survey) which were financed internally or by a parent firm (INPARFND), the percentage of funds spent on R&D financed by government (GOVFUND), and the square of the latter (GOVSQ).

The model was tested for heteroscadisticity of the form:

$$E(u_i^2) = \sigma^2 (SALET78_i)^\alpha$$

where u_i is the disturbance term and the subscript i denotes the observation corresponding to the i^{th} firm. A Goldfeld-Quandt test indicated the presence of heteroscadisticity in the untransformed model and its absence when all variables were divided by the square root of SALET78. This implies that the variance of the error terms in the weighted model are constant ($\alpha = 1$). Hence the transformed model yields the unbiased and efficient estimates of the coefficients of the original model.

The results of the ordinary least squares regression are summarized in Table 15. Among those results we found that the size of a firm's R&D spending is significantly and positively related to sales. However, the coefficient of SALESQ is significantly negative, indicating that R&D expenditures increase with firm size but at a decreasing rate. The estimated function reaches a maximum at a sales level of 93.4 million. Neither of the coefficients for foreign-ownership or percentage of R&D financed internally proved to be significant. GOVFUND obtains a positive and significant coefficient but GOVSQ obtains a significantly negative coefficient. Thus increased government aid positively influences the level of a firm's R&D spending but at a decreasing rate. The results indicate that the positive effect of government subsidies persists up to a maximum support level equal to 46.1% of the firm's total R&D expenditure. Of the 57 firms observed in the sample, 8 had received public funding in excess of this level.

The results pertaining to the effectiveness of government support for privately financed R&D concur with those from past studies. Our findings concerning the sign and significance of the GOVFUND and GOVSQ coefficients are consistent with Hewitt's findings for SIC 335 and with those of Howe and McFetridge for the electrical goods sector as a whole. The results for foreign ownership are also consistent with Hewitt's study but at variance with the results obtained by Porter for 84 industries and by Howe and McFetridge for SIC 335.

On the basis of the findings we may conclude that public subsidies result in a net increase in the social allocation of resources to R&D in the electronics industry. However, the results form this and other studies indicate that a firm's R&D expenditure becomes increasingly inelastic with respect to subsidies as the level of support increases relative to the total R&D outlay. Similarly, the positive relationship found between the level of R&D expenditure and sales diminishes as sales increase. Since the vast majority of electronic firms in Canada have annual sales far below the level (93.4 million) at which R&D no longer increases, the results lend some credence to the view that firm size may impede R&D spending in the industry.

Table 15

Regression Results: The Determinants of Firms' R&D Expenditures

Dependent Variable : RDT78

Explanatory Variable	Coefficient	t Statistic
SALEST78	0.0395	6.65**
SALESQ	-2.1151×10^{-10}	-4.57**
FORGNOWN	-3.5557×10^{4}	-0.68
INPARFND	9.3237×10^{3}	0.19
GOVFUND	4.2541×10^{5}	1.89*
GOVSQ	-4.6185×10^{5}	-1.37*

$R^2 = 0.5659$

Joint F test on coefficients of SALET78 and SALESQ (null hypothesis: both coefficients equal zero): $F(2,50) = 24.9$**

Joint F test on coefficients of GOVFUND and GOVSQ $F(2,50) = 2.69$*

* Significant at the 90 per cent level

** Significant at the 99 per cent level (two-tailed test)

Footnotes

1. K. Arrow, 1962, "Economic Welfare and the Allocation of Resources for Invention" in Universities National Bureau Committee for Economic Research, The Rate and Direction on Economic Activity (Princeton, Princeton University Press).

2. W. Nordhaus, 1969, Invention, Growth and Economic Welfare (Cambridge, MIT Press); D. McFetridge, 1977, Government Support of Scientific Research and Development: An Economic Analysis (Toronto, University of Toronto Press).

3. W. Nordhaus, op. cit. , pp. 70-75.

4. The rate of cost reduction (i.e. OP_1-OP_2/OP_1) is assumed to be a positive function of the resources allocated to R and D. This rate determines both the social benefit from the invention and the royalty income of the inventor (private benefits). The partial inappropriability of the social benefit by the inventor under a finite patent term implies that for a given rate of cost reduction marginal social benefits exceed marginal private benefits. Therefore the private sector will underallocate resources to R and D since the rate of cost reduction which maximizes profits is less than the socially optimal rate of reduction. D. McFetridge, 1977, op cit., pp. 13.

5. G. Eads, 1974, "U.S. Government Support for Civilian Technology: Economic Theory vs. Political Practice", Research Policy 3, pp. 2-16.

6. K. Arrow, 1962, op. cit., K. Arrow and R. Lind, 1970, "Uncertainty and the Evaluation of Public Investment", American Economic Review 60.

7. K. Arrow, and R. Lind, 1970 op. cit.

8. D. McFetridge, 1977, op. cit.

9. Ibid. For example Porter (1980) and Howe and McFetridge (1976) found that with all other relevant factors held constant, foreign ownership has a significantly negative effect on R and D spending. Furthermore, McFetridge (1977) had found that the probability of a foreign-owned firm applying for and receiving a subsidy was greater than that for a domestically owned firm. See M. Porter, 1980, "Research and Development Spending" in R. Caves et al., Competition in the Open Economy: A Model Applied to Canada (Cambridge, Harvard University Press); J. Howe, and D. McFetridge, 1976, "The Determinants of R and D Expenditures", Canadian Journal of Economics, (9); D. McFetridge, 1977 op. cit.

10. Cited in A. Cordell, 1971, The Multinational Firm, Foreign Direct Investment and Canadian Science Policy (Ottawa, Science Council of Canada).

11. J. Howe, and D. McFetridge, 1976, op. cit.

12. For details on the data collected by this survey see De Metto, McMullen and Wills (1980).

CHAPTER 5

SUMMARY AND CONCLUSIONS

The objective of this study is to provide an analysis of the recent growth, structure and performance of the Canadian electronics sector, and to suggest, where appropriate, guidelines for R&D and commercial policy for the industry.

Chapter 1 provides a statistical delineation of the industry which facilitates the gathering of data on shipments, inter-industry trade, domestic market size, concentration, productivity, and other structure and performance related variables. Chapter 2 investigates the nature of structural change in the industry, its underlying causes and its impact on performance. The discussion of trade policy in Chapter 3 is principally concerned with whether considerations for scale efficiency indicate a need for sectoral trade liberalization. Lastly, Chapter 4 addresses the issue of market future in the private allocation of resources to R and D and the appropriate response by the state.

SUMMARY OF FINDINGS

Structure and Performance

The electronics industry can be classified as loosely oligopolistic in structure. Although Northern Telecom accounts for 30 per cent of industry sales, the balance of sales is distributed among 711 other firms. Moreover the market power of the industry's largest firms, the majority of whom are foreign-owned, is held in check by the industry's wide exposure to international trade.

Both static and dynamic production economies are present in the manufacture of electronic goods. Economies of plant size are found in the production of mature products such as televisions and radios. Learning economies, on the other hand, pervade among the more technologically advanced sectors of the industry (components, systems, microprocessor based equipment etc.). Most estimates of learning in the industry suggest that these economies are substantial with unit costs typically falling 20-30 per cent with every doubling in cumulative output. There are also ancillary economies of scale in marketing and product development. These firm size economies are emphasized in the more innovative sector of the industry where R&D and marketing expenses can account for as much as 50 per cent of the unit cost of new products.

In most areas of the industry MES is very large relative to the size of the domestic market. This implies that scale efficiency would dictate a very concentrated market structure. The extent to which the actual level of industry concentration differs from that necessitated by scale efficiency can be attributed to the level of domestic protection. Canadian tariffs on electronic goods range from 5-20 per cent although the majority of imports are taxed in the neighbourhood of 15 per cent. In the past, tariffs provided a sufficient level of effective protection to permit suboptimal size plants to compete in the domestic market. However, recent dramatic increases in the level of import penetration in the domestic market suggest that this may no longer be the case.

With the exception of the United States, Canadian protection is modest in comparison to the trading practices of other producer nations. Although foreign tariffs are roughly comparable to Canadian ones, Japanese and European manufacturers are afforded extensive non-tariff protection.

A variety of non-tariff barriers, notably domestic content regulations in public procurement, have effectively closed Japanese and most European electronic markets to Canadian exports.

Turning to performance, there are several encouraging indications that many industry sub-sectors have become increasingly competitive both at home and abroad. One indicator of improved performance is the exceptional growth in labour productivity which has taken place in several sectors of the industry over the last decade. For example, Real Domestic Product per man-hour grew between 1971-1979 at an annual average rate of 11.7 per cent in the computer sub-sector and by 11.6 per cent in the consumer products sub-sector.

Another indicator of performance is trade. In this respect our data indicates that the industry has become increasingly internationalized with greater specialization by domestic firms. This is manifest in the significant increase in both the level of import penetration and the ratio of exports to shipments. Although the growth in intra-industry trade has led to a substantial increase in Canada's trade deficit in electronic goods, exports have grown rapidly and account for over half of shipments in a number of industry sub-sectors. If exports are an indication of international competitiveness, the observed changes in the pattern of intra-industry trade should be favourably considered from a performance standpoint.

Rationalization

The electronics industry has undergone a number of structural adjustments over the last decade. In response to increasing import competition, domestic producers have become more efficient by concentrating production on a narrower range of goods, thereby reaping economies of specialization. The rationalizing effects of intra-industry trade underlie the impressive growth in industry productivity and exports during the 1970's.

Trade induced specialization cum rationalization has been noted in at least two industry sub-sectors (consumer products and computers) and a wider incidence of restructuring may be inferred from the results of a regression analysis of intra-industry trade data. Case studies of rationalization in the consumer product and computer sub-sectors reveal that major structural changes in the industry have involved foreign-owned multinationals. The rationalization of foreign-owned subsidiaries has chiefly entailed the replacement of branch plants by more specialized and scale efficient plants which produce specific product models for the international markets of parent firms.

It is noteworthy that in many instances rationalization among foreign-owned electronic firms has been encouraged by public intervention in the industry . For example, federal procurement and moral suasion has been used effectively to secure specialization agreements from multinationals engaged in the manufacture of mainframe computers. Similarly, a duty remission program, coupled with pending tariff reductions has provoked a major restructuring of the largely foreign-owned television manufacturing industry.

Trade

The size of the domestic electronics market is insufficient to justify either a terms or trade or infant industry argument for protection. The terms of trade argument can be readily dismissed as inapplicable to any sub-sector in the electronic industry, since Canada is in each sub-sector too small a purchaser for tariff induced changes in its consumption to be able to affect world prices. Similarly, an infant industry argument is suspect on the basis of our previously reported finding that MES in electronics is very large relative to the size of the domestic market. Since domestic producers would be for the most part unable to achieve scale efficiency in a protected market, there is no reason to assume that protection would significantly improve the industry's productivity.

There is also evidence that tariffs on electronic computers and semiconductors adversely affect the international competitiveness of electronic end-product manufacturers who rely on these products as intermediate inputs. The tariff on computers raises the costs of data processing firms by around 5 per cent while duties on integrated circuits and other microelectronic components places non-integrated manufacturers of final products (telecommunication equipment, industrial control panels, word processors etc.) at a competitive disadvantage in world markets.

R&D

A rationale for public support of industrial R&D emerges from the problems of inappropriability and risk. The imperfect private appropriability of the returns to R&D militates against the market allocating the socially optimal level of resources to innovative activity. In a world of perfect certainty, a subsidy induced increase in the private allocation of resources to R&D will effect an improvement in social welfare. The introduction of uncertainty may suggest that the state assume a further risk bearing role by investing in risky projects whose expected social rate of return is positive. However, such intervention can only be justified if the state can absorb risk more efficiently than the market. It is tentatively suggested that economies of scope should permit the state to achieve such an advantage. This follows from a perception that the state's existing activities and institutional infrastructure should enable it to incur lower administrative costs in the monitoring and evaluation of its portfolio of R&D investments.

The efficacy of support programs with respect to increasing the social allocation of resources to R&D was tested in an econometric investigation into the determinants of R&D expenditures by firms in the electronics industry. While the results of this test indicate that subsidies do not simply displace R&D expenditure, there is nevertheless evidence that the rate of increase of a firm's total R&D expenditure decreases as the percentage of its R&D outlays financed by government increases. This relationship was found up to a support level of 46.1% of R&D cost whereupon additional subsidies failed to elecit further private expenditure. These results suggest that diminishing social returns may be associated with increased subsidization.

Among other results we found that the level of a firm's sales has a significantly positive influence on R&D spending but that spending increases with sales at a decreasing rate. Neither foreign-ownership or the percentage of R&D funds financed internally had any significant impact on the level of electronics firms' R&D outlays.

POLICY RECOMMENDATIONS

Trade Policy

1. The infant industry argument for protection appears to be inapplicable to any industry sub-sector. Accordingly, there is scope for industrywide trade liberalization. There is a rationale for unilateral action in reducing tariffs on components and computer sub-sectors whereas conditions in other sub sectors suggest maximum social benefits would be achieved through multilateral liberalization. It is important that a curtailment of non-tariff barriers, particularly protectionist public procurement practices, be included in any multilateral or bilateral agreements.

2. Given the very high degree of foreign-ownership in the industry, a successful adjustment to liberalized trade would require intra-firm rationalization by multinationals currently operating in Canada. In sub-sectors where domestic productivity is lower than in the U.S. (i.e. consumer products and computer assembly), liberalization could pose potentially serious dislocation problems. Such effects could be mitigated by specialization agreements which compel multinationals to rationalize their Canadian operations as opposed to simply terminating them. Thus, it is essential that a policy of sectoral trade liberalization be accompanied by parallel agreements.

R&D Policy

1. Consideration for both inappropriability and risk suggest a mix of policy instruments. Direct subsidies are fitting to counter the private inappropriability of the social returns to R&D. Government loans and/or equity participation is appropriate to assist firms in undertaking risky but socially desirable projects. Both instruments are discretionary in the sense that the amount of support given to an individual R&D project can be determined on the basis of expected social benefits. For this reason discretionary support programs are preferable to tax incentives wich operate automatically, and indiscriminately through the fiscal system.

2. The endorsement of support mechanisms which facilitate a case-by-case approach may require some qualification in view of certain practical considerations. One consideration is the cost of assessing a multitude of subsidy requests, many of which may pertain to relatively minor R&D projects.

The imputed cost of public scrutiny of each subsidy request may constitute a non-trivial cost which significantly lowers the expected social rate of return on a small project. A compromise between the benefits of discretionary support programs and their administrative cost could entail the employment of fiscal incentives for relatively minor R&D expenditures and a case-by-case evaluation of large projects.

Another difficulty arises from the budgetary implications of discretionary programs. Since the aggregate level of support depends on the costs and benefits of each prospective project, the government has no means of determining its ex-ante expenditure. This may be awkward from a practical standpoint given the nature of the budgetary process. Again, a compromise could be achieved by calculating the amount of funds that would have been required to fund all worthy projects in the current year, and then to budget this amount plus an inflation allowance for the following year.

3. The finding that government subsidies do not exert a significantly positive influence on private R&D expenditure beyond a support level of 46.1 per cent suggests a rationale for imposing a percentage ceiling on subsidy funding for any single R&D project. Current cost sharing rules which restrict federal subsidies to no more than 50 per cent of a project's cost are consistent with our results. However, current regulations apply to only foreign-owned firms whereas the finding obtained in this study suggests that funding ceilings should be applied to all subsidy requests regardless of ownership. It should of course be noted that subsidy ceilings do not preclude the possibility that additional support in the form of either equity or debt financing could be obtained from the government, providing that such support is warranted by risk considerations.

<u>Policy Framework</u>

A final concern is the need to link together R&D and trade policy within a policy framework that promotes further specialization. This may imply that it is not in Canada's long-run interests to compete in areas of the electronics industry where there are substantial economies of scale such as microelectronic components, but instead develop policies which facilitate the use of these components in electronic end-products. In this way, Canada, as a consumer of intermediate goods can reap the benefits of large subsidies in chip technology made by foreign governments without having to bear any of the costs. This illustrates that although policies followed by other countries will affect optimum domestic policy, it does <u>not</u> mean that Canada must match these policies in order to have a successful electronics industry.

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