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Not a Long Shot

Canadian Industrial Science and
Technology Policy

Guy P. Steed

CANADA INSTITUTE FOR S.T.I.
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Guy P. Steed

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Preface

The Science Council of Canada initiated the preparation of this background study in 1987. The study is designed to address, from a science and technology policy perspective, major trends in international competition, developments in Canadian policy and strategy, major and minor policy issues in industrial technology in the late 1980s, and emerging issues for the 1990s.

Largely completed by mid-1988, the study provided background for a Science Council statement, *Gearing Up for Global Markets: From Industry Challenge to Industry Commitment*, released in October 1988. An earlier version of the free trade agreement section of Chapter 5 was also released in 1988, as a manuscript report, to contribute a science and technology component to the free trade discussions. The tax reform section of Chapter 5 provided background for a Science Council statement submitted to the Minister of Finance on the impact of tax reform on research and development.

Guy P. Steed
Director of Programs
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The Overriding Issue: Technology, Innovation, and Competitiveness

A new era

Canada is undergoing a science and technology awakening. It could not happen at a more opportune time. As we approach the next century, a golden era of science and technology is contributing to a historic economic transition. To emerge among the rich and strong, Canadians must sweep in on the new tide of technology. And to do so our science and technology policy must be honed to make it better than a long shot.

It is human imagination that is building the 21st century out of sand and clay.... We are increasingly moving from an age of things to an age of thoughts, an age of mind over matter. In this new age, it is the mind of man...that is our most precious resource.... Gold, steel, oil — these were the treasures of the past that made people rich and nations strong. Today, the premium is on the human heart and mind. They can't be locked in a vault, rationalized or expropriated.¹

In these words spoken in 1987, Ronald Reagan, then president of the United States, acknowledged the extraordinary, far-reaching prospects of the rapid advances in superconductivity that have caught the imagination of scientists and the business community and may herald a new era of technology.

As this new era unfolds, Canada must move quickly. She must become less dependent on industries based on what Mr Reagan called the "treasures of the past," although such industries will remain part of her economic fabric and must continually improve their competitiveness. But the overriding issue facing Canada is how to craft and implement science and technology (S&T) policies to encourage innovation and the application of technology to all facets of product development, production, and service. Thus Canadian industry, by becoming stronger, more productive, and competitive in global markets, will allow Canadians to maintain, indeed enhance, their standard of living.

This report seeks to provide, from a policy perspective, a broad overview of emerging S&T patterns and major global and Canadian developments in industrial technology. It identifies, through scanning and consultation with the industrial S&T community, some leading current (1987-88) and pending issues regarding the industrial R&D base, industrial modernization, and technology diffusion, and comments on their adequacy. Finally, it recommends a dozen priority areas to strengthen the strategy for S&T-based economic renewal. The report thus contributes to the ongoing task of making Canadian technology policy more of a sure bet than a long shot.

The report does not address the many important related issues on public acceptance of science and technology, its socioeconomic and environmental impact, science education and literacy, university and government research, or emerging science and technology. They are the focus of other work that continues at the Science Council of Canada.

Fundamental changes in the world economy

Canada must design its S&T policies in the context of the changing fabric of the world economy. Several major forces are converging to produce profound structural adjustments and a new global order.² For example:

- The primary-products economy has come uncoupled from the industrial economy in the sense that increases in industrial added value no longer imply matching increases in the use of primary products.
- In the industrial economy itself, production has come uncoupled from employment — increases in production do not generate matching increases in employment.
- Capital movements, primed by Japanese global financial dominance rather than trade (in goods and services), have become the driving force of the world economy. The two have not quite come uncoupled, but the link has become loose and, worse, unpredictable.

Two key features of global economics, military spending and the health of the environment, are eloquently addressed in the 1987 report of the World Commission on Environment and Development.³ In 1985 world military spending exceeded U.S. \$900 billion, more than the total income of the poorest half of humanity. The commission reports:

The distorting effects of the "arms culture" are most striking in the deployment of scientific personnel. Half a million scientists are employed on weapons research worldwide, and they account for about half of all research and development expenditure. This exceeds the total combined spending on developing technologies for new energy sources, improving human health, raising agricultural productivity and controlling pollution.

The global context within which Canada's S&T policy is to be moulded also includes the fading of the former superpowers, the emergence of the Asia-Pacific economic power, and the wide-ranging effects of the new information technologies, biotechnologies, and advanced materials. Let us look at these three developments.

The Soviet Union and the United States are finding it costly to retain their special positions as superpowers and to sustain military expenditures far above the world average. Those expenditures affect the focus of their research and development (R&D) efforts, but we must also note the spread of technological innovation into the civilian sector from expenditures on military R&D. The Soviet Union, through significant new policies, is attempting to liven its faltering economy. It is trying to expand trade with the West and in 1987 authorized joint ventures within the Soviet Union with Western partners, in part to upgrade technology and management.

The soaring eagle is also faltering. The Pentagon faces declining technological leadership and decay in the defence industrial base.⁴ Growing American government deficits, associated with enormous military expenditures, raise serious questions about whether they are sustainable and whether they detract excessively from the capability of civilian engineering and manufacturing. The massive, continuing American trade imbalance has produced a net external debt higher than that of any Third World debtor. This raises spectres of disruptive protectionism and calls for a managed trade turnaround that will have to be driven by high-value manufactured goods and skill-intensive services. This in turn requires both massive investment in R&D and even greater expenditures for commercial application at a time when American corporate spending on R&D is declining and fewer engineers are graduating from American colleges and universities; meantime, the accelerating pace of obsolescence means that industry depends more on foreign markets to recoup costs. As American industries have become subject to greater global competition, there has been an explosion of

interest in improving technology transfer, domestic and foreign, and the aggressive use of intellectual property litigation as a competitive weapon.

The growth of Asia-Pacific economic power is expected to continue over the next decade. Many countries in the region are projected to raise their incomes per capita roughly four times faster than Western industrialized countries. Their success in world markets, which is helped along by the pace with which exchange rates have been adjusting, is leading to trade tension with developed Western economies, pressures for protection, and now a linking between former foreign rivals to blur the battle lines. The Japanese are poised to become major players in the international takeover market. A key trend is for American technological and marketing expertise to couple with superior Japanese manufacturing skills. This may, however, undermine the long-term ability of American industry to compete if much manufacturing migrates offshore.⁵

The wide-ranging effects of new information technologies, biotechnologies, and advanced materials are reducing reliance on natural resources and requirements for land, labour, and capital. They are spawning entirely new industries and shifting the boundaries between manufacturing and services. In reality, manufacturing and services depend heavily on one another, especially in large countries. In the United States and Japan, for instance, the international infrastructure for services is critical for the long-term competitiveness of firms in many industries; manufacturing multinationals bring in tow a sophisticated cadre of service professionals — designers, accountants, lawyers, engineers, architects, and specialists in software, hotels, and real estate.⁶

Manufacturing matters, even in so-called postindustrial societies, which have a large core of service employment and in which growth is tied to the ability of manufacturing industry to compete internationally. And there is a strong technology and science foundation to knowledge-based services, centering on the modelling of product design and production processes. In many service industries, competitiveness, both domestic and international, increasingly depends on transactional and analytical applications of computer systems, and on telecommunication links for computers.

This, then, is the global context in which Canadian S&T policy must be crafted. In most major industrial economies the share of manufacturing output in gross domestic product has actually changed relatively little over recent decades, although it has provided a smaller

share of total employment. And the reductions in blue-collar jobs, as knowledge and capital are substituted for manual labour, have in many cases been outweighed by the expansion of service-sector jobs and growth of knowledge-intensive industries. Indeed, job growth tends to have been largest where there has been the most intensive application of new technologies.⁷

In three key respects the information technologies are already a major force behind social and economic change. First, they are significantly shifting the balance of rewards toward flexibility, novelty, and quality. In the world economy, information is becoming the critical raw material. Inquiring, communicating, evaluating, and deciding predominate, and information often has greater value the faster and further it is moved. The balance is shifting from the previously dominant technologies that emphasized economies of scale in the efficient production of standardized commodities. The global economy of the past decade or so is one in which many large manufacturing firms have reduced their workforce and in which small firms, many in the service sector, have become by far the dominant source of new jobs in advanced industrial countries.

Second, the information technologies are driving the growth and the growing capital intensity of the service sector. Much of that growth is oriented to serving other businesses. As modern economies move increasingly from tangibles to intangibles, hardware to software, and quantity to quality, an efficient, effective information infrastructure becomes more important.

Third, the revolution in information technologies has stimulated productivity and ever-greater international integration of production, services, and markets. This in turn heightens pressures for joint economic management among nations, enables a transition to more sustainable patterns of international trade balances and global debt, and alters our notions of sovereignty. The need for international solidarity to sustain the new global order may increasingly override domestic political priorities.

The problems of international competitiveness

In this shifting world economy, most developed countries face a deep-seated problem of international competitiveness. Yet there is limited agreement on the bases of the problem and what to do about it.

However, three broad attitudes dominate when assessing how government policy helps create or destroy competitive advantage:⁸

- A macro focus (associated with what has been called “the British disease”), which emphasizes getting the macro-levers of power right — influencing the quantity and quality of labour, capital, and technology. This focus is on problems such as the relative skills of the labour force, the lack of integration of technological and long-term industrial policies, the preoccupation with consumer values, and the need to reduce deficits, coordinate policy internationally, and promote free trade.
- A micro focus that is concerned with “flabby” management. It stresses overstaffing, gaps in management skills, including the lack of integration of R&D with production engineering and marketing, and such mistaken preoccupations by management as those with paper entrepreneurship, an obsession with mergers and acquisitions, and short-term gains.
- A “convergence” focus, which denies that the competitiveness problem is structural. Those who hold this view see a convergence of income levels and a reduction in differences in productivity between developed countries. This focus finds no evidence, for instance, of “Eurosclerosis” — an alleged technology gap between Europe and the United States and Japan.⁹ Others see a wide variety of technological indications that Japan has opened a “technology gap” over other developed countries.¹⁰ Some find no justification for assuming general European technological backwardness, but there are indications that economic development (gross domestic product per capita) is closely correlated with the level of technological development, as measured through R&D and patents.¹¹

Policy considerations

This report argues broadly that for Canada’s future prosperity, manufacturing capability matters, technology policy matters, and geography matters. It suggests:

- That the development and application of technology increasingly determine growth and international competitiveness;

- That there have been major changes recently in national industrial systems (particularly in their systems of innovation), which are becoming more intertwined in partnerships and collaboration;
- That research is imperative, but the S&T system requires better focusing and more careful coupling with industry to strengthen manufacturing capability and generate national wealth;
- That the Canadian system is doing better than it was, but hardly well enough;
- That S&T policy issues have finally moved at least from the periphery to centre stage;
- That the S&T aspects of how tax reform, free trade, and regional development are addressed will probably have a significant impact on industrial R&D and innovations;
- That S&T policy is increasingly driven by regional or local concerns, with the provinces and larger cities active in defining and addressing many of these issues;
- That a series of significant global and domestic S&T policy issues is emerging; and
- That in resolving these issues the premium is on private-sector vision, imagination, leadership, commitment, and self-help as well as public-sector collaboration. If private-sector self-help is lacking, Canadians will almost certainly expect their governments to become much more than facilitators of the development and diffusion of industrial technology.

The key is a grassroots approach to the crafting of the S&T policies and strategies that will enhance Canada's comparative advantage. This requires an institutional framework within which individuals and organizations among the leading sectors at all levels of government can take part. From this must flow a consensus on long-term goals that are established on the basis of likely change; there needs also to be flexibility to adjust to new, unexpected developments.¹² Crafting a strategy that reconciles change and continuity requires a synthesis of the future, the present, and the past, an ability to detect emerging patterns and help those that are positive to take shape, and a climate in which a wide variety of strategies can grow. In detecting emerging patterns, governments will be able to sense when to exploit established strategies and when to encourage new ones.¹³

Much has already been achieved over the past few years. Much more needs to be done, in a process of continual assessment and adjustment. This report identifies priority areas and actions to help strengthen the national strategy for S&T-based industrial renewal. It hopes to make technology policy less of a long shot at a time when education and research have become both the central mechanisms for creative adjustment and the cornerstones of future Canadian competitiveness in a rapidly changing global economy.¹⁴

Chapter 2

International Jockeying for Position

Innovation and industry

National S&T systems involve the complex interactions of many institutions. They are increasingly being honed to contribute to economic growth and are often driven by defence and health spending and constrained by the need for industry to conform to regulation. But the exact relationship between investment in technology and innovation and national economic growth and industrial adjustment continues to evade measurement.¹ Certainly there has been significant growth worldwide in industrial R&D, but this seems not to have led to commensurate growth in productivity and economic performance over at least the past decade.

Various factors have converged to undermine, perhaps temporarily, the coupling between S&T advances and global economic performance. Some relate the economic crisis of recent years to the timing of long waves of technological innovation, the exhaustion of the previous techno-economic system, which is no longer able to raise productivity significantly, and the disruption of a flood of new technologies.²

Product design and technical sophistication increasingly distinguish the products and industries in which high-wage countries can compete in world markets. For such countries, the real economic challenge consists not of offering goods at lower prices, but of offering new products and services that represent value for money.³ Whether they can do so depends in large part on the ability to educate people, to encourage their ideas, and to support a science culture.

The conviction is now widespread that S&T-driven innovation is an important catalyst of wealth creation and industrial change and that its impact is becoming more pervasive — sometimes radical — in inducing structural change, shifting the international terms of competition and generating new methods of production.⁴ CAD-CAM (computer-aided design, computer-assisted manufacturing), for instance, is flexible enough to obtain economies of scale and product differentiation while also responding rapidly to changes in market demands. Its adoption in

turn requires new types of organization. Many firms face a new world, one in which flexibility downstream, in assembly for instance, and innovation upstream, in subassemblies and components, are critical to manufacturing renewal.

Research, including fundamental research, both responds to and underpins much of the modern technological system. Hence the vital role of scientific progress. What most drives the capitalist engine is proprietary technological knowledge. Scientific knowledge that is not protected, at least temporarily, and fails to contribute to proprietary technology by one mechanism or another provides little basis from which to build and sustain the competitiveness of an advanced industrial economy.⁵ It is wrong, however, to conclude that major economic benefits derive from leadership at the scientific frontier.⁶ Innovative firms often fail even when imitative firms succeed. Scientific excellence not matched with managerial and engineering skills, as recent British experience demonstrates, generates little competitive advantage.

Even among large innovative companies, the competitive struggle rarely revolves around bringing the latest scientific breakthroughs to market. Rather, it lies for many companies in perfecting well-established product lines and mastering the product design and manufacturing cycle.⁷ Often it involves the capacity to make vital but undramatic innovations, frequently in response to suggestions from product users on how to stretch technologies and make products perform better and meet new needs.

The broad industrial structures take a long time to change. Technological advances, despite their pervasive impact on individual firms and across industrial sectors, have not in recent years given rise to major shifts in the proportion of manufacturing output in advanced industrial countries that have a high R&D intensity (Table 1).

What they have contributed to is significant shifts in the international pattern of specialization and competitiveness not just in Japan but also in those countries, Canada included, that are highly exposed to foreign competition in manufacturing (Table 2).

Driven by the need for economic renewal, and presuming that the main rewards accrue to those who dominate the sectors of high R&D intensity, industrial countries have been jockeying for a lead in the high-tech race. Yet Canadians still appear surprisingly oblivious to this. According to a June 1987 Gallup poll, only 38 per cent are aware of such

Table 1. Composition of Manufacturing Output for Selected Advanced Industrial Countries, 1970 and 1983 (percentages).

	High R&D intensity		Medium R&D intensity		Low R&D intensity	
	1970	1983	1970	1983	1970	1983
Australia	7.3	7.2	29.2	35.4	63.3	57.2
Belgium	6.8	7.0	30.3	37.1	62.8	55.7
Canada	8.6	7.1	28.3	32.1	62.9	60.6
Finland	3.6	4.9	18.7	18.8	77.6	76.1
France	10.6	12.7	28.5	33.8	60.8	53.5
Italy	11.7	10.9	28.6	32.2	59.4	56.8
Japan	14.4	16.2	32.2	34.1	53.2	49.6
Netherlands	13.2	12.5	19.6	25.4	67.1	62.0
Norway	5.9	5.9	21.3	25.5	72.7	68.5
Sweden	9.8	9.8	27.0	29.1	63.1	61.0
United Kingdom	12.5	11.4	29.7	28.1	57.6	60.4
United States	14.9	16.6	31.7	30.8	53.2	52.5
West Germany	12.3	12.8	32.2	40.7	51.9	46.4

Source: Organization for Economic Cooperation and Development, *Structural Adjustment and Economic Performance* (Paris, 1987): 254.

Table 2. Apparent Comparative Advantage of Manufacturing Industry, 1970, 1980, and 1985 (Organization for Economic Cooperation and Development average = 100).

	High R&D intensity			Medium R&D intensity			Low R&D intensity		
	1970	1980	1985	1970	1980	1985	1970	1980	1985
Australia	16	24	17	66	54	83	175	198	187
Canada	51	39	40	123	108	126	97	122	108
European Economic Community (EEC) ^a	88	85	75	108	103	100	98	104	116
Japan	114	128	133	77	100	105	120	86	68
Sweden	68	71	63	83	85	87	135	135	144
United States	146	142	149	108	107	96	67	66	67

^a Excluding intra-EEC trade.

Source: Organization for Economic Cooperation and Development, *Structural Adjustment and Economic Performance* (Paris, 1987): 214.

intense international competition. Among this group, 69 per cent consider it “very important” and 27 per cent “fairly important” that Canada become a leader in high-tech areas such as computer science or biotechnology. It seems that many Canadians fail to see a strong link between domestic technological advances and rising standards of living. The failure is serious, particularly if it undermines the political will to tackle S&T issues.

International competition among the sectors of high R&D intensity has generated tensions, some of which are exacerbated by concerns about government intervention in trade. These concerns, which vary between sectors, are about government support for R&D and government-sanctioned joint R&D programs, government control of technology transfer on security grounds, government and public procurement, spin-offs from military or space programs, and the role of standards, registration, tests, and export promotion.

Industrial adjustment is proving a fierce challenge for many sectors. S&T capabilities among advanced countries are becoming less disparate, the dissemination of S&T information is accelerating, and the period in which individual firms can exploit technological superiority is shortening. The last factor — the reduction in the life-cycle of technological products — means that R&D costs must be recouped faster and research findings must be translated more speedily into process or product development. And for most firms, especially those in small and medium-sized countries, the benefits must be reaped from serving international or global markets early in the product life-cycle.

The hectic pace of the race and its scale have also driven firms — and not only those in R&D-intensive industries — increasingly toward interfirm cooperation, alliances, consortium agreements, and cooperation with universities and government laboratories.⁸ Many companies are driven by the trend to globalization, and harnessing S&T in the interests of economic renewal has become big business. And each advanced country, faced with its particular problems, institutions, ideologies, pressure groups, and priorities, is hurriedly experimenting with its own strategy.

Complicating the task has been the rapid globalization of industry, promoted by multinational firms and rooted in market homogenization, diminished transport costs, improved communications, and lowered trade barriers. Experience in this globalization increasingly shows that even those firms and nations that are major technological originators can

lose ground in the commercialization of modern technologies. Where imitation is easy and legal protection of intellectual property is not effective, the profits from innovation may accrue not to the original innovator, but to those who own various complementary production, marketing, or after-sales support assets.⁹ The trick is in finding where a lead can be protected and how to protect it.

National strategy is also important. To reap the rewards of their innovations, innovating nations must enhance the protection of intellectual property. Where such protection is infeasible, the nation must be able to capture the spillover benefits from such innovation. Many benefits tend to accrue to early adopters. An innovation strategy, therefore, requires a focus not simply on R&D, but also on complementary assets and the underlying infrastructure that supports early adoption. The spillover benefits from medical research, for instance, may be hard to capture for a country that does not have the necessary industrial infrastructure and other complementary assets. A major issue, therefore, is how best to couple the S&T and industrial systems.

One aspect of that coupling concerns the sources of innovative activity. Industrial innovation now seems to be concentrated more at the ends of the size spectrum, among small and large firms.¹⁰ In the case of small firms, statistics on the amount of R&D they do are not a good measure of their innovative activity. They tend to flourish by providing inputs — usually components or services — into a production process, often that of a large, innovative firm. Large firms, whose innovative activities tend to be more R&D-based, are more usually associated with product than process innovations. R&D-based innovations, however developed, are generally put into practice by large firms; appropriability — or technological ease of entry — differs considerably between industries.¹¹ And very large firms appear to result from the continuing exploitation of appropriable technology, producing lines of related products that emerge from R&D, that increasingly are marketed internationally, and that are managed through smaller, increasingly efficient units.

Industry and national systems of innovation

To move from the old to the new technology, indeed to a modern information economy, involves breaking down many solitudes. To animate and make effective a national system of innovation requires the

interaction of many previously disparate organizations. Many social and institutional changes are needed to sustain appropriate links between science, technology, education, training, government departments and laboratories, and industrial firms.

Take the case of Japan, which has not only proved the most successful nation in developing and embracing the new technologies, but has also opened a new “technology gap.” Major features that distinguish the Japanese system of innovation from elsewhere are:¹²

- A systems approach by companies to process and product design, integrating R&D with engineering design, procurement, production, and marketing;
- Education, training, and related social policies, contributing to a workforce with skills and attitudes conducive to rapid technical change and high-quality output;
- The formation of conglomerates into a flexible industrial structure able to allocate resources for long-term goals in capital investment, R&D, new technology, and industrial training;
- The formulation and implementation by the central government of long-term policies for public- and private-sector S&T; the necessary technology forecasting helps heighten awareness, secure consensus, and animate key participants.

National competitiveness increasingly depends on the effectiveness of the national system of innovation. It involves more than the competitiveness of the nation’s firms; it also depends on the strength and efficiency of the productive structure and technical infrastructure and on the existence of other factors on which successful business management can build.

S&T, industrialization, and internationalization

Science and technology in advanced countries have become more oriented to industry. Levels of industrial R&D increased after the mid-1970s and grew particularly rapidly after 1979, especially in Japan. Moreover, business supplanted government as the single largest source of R&D funds in many countries. Projects conducted jointly by industry and research institutes also became more popular — in Sweden, for instance, the number of institutes grew from seven in 1964 to 28 in 1988.

The work done by the institutes may be called precompetitive, in that it creates basic knowledge available to all from which proprietary knowledge can be developed.

Business during the 1980s also increasingly extended its role in basic research to information technologies, biotechnologies, and advanced materials. Most members of the European Industrial Research Management Association emphasize their need to do basic research because it:

- Leads to new developments;
- Helps them to understand processes and products;
- Keeps them informed of scientific advances;
- Maintains scientific and technological standards; and
- Helps motivate researchers.

Companies that do not do strategic basic research find it difficult to develop the expertise to build on the results of basic research.¹³

In the United States and parts of Europe, some of the basic research funded by business is conducted in universities or in university-controlled firms. Universities in most advanced countries have also increased their cooperation with industry in research and technology transfer to industry; in many cases government programs promote such collaboration. One key difficulty in university-industry collaboration has been that of forming multidisciplinary research teams. Consider, for example, the new Link initiative in Britain. In 1988 the British government ceased to support R&D conducted by single companies, switching its emphasis to collaborative efforts, domestic and foreign.¹⁴

The S&T system has also become rapidly more internationalized. Not only do multinational firms have research laboratories in several countries, but many firms are now forming joint ventures or precompetitive research alliances with foreign companies, sometimes taking advantage of government programs such as ESPRIT and EUREKA. For example, the Dutch firm Philips, the American Telephone & Telegraph Company, Siemens of West Germany, and the British General Electric Company have a joint venture. Similarly there has been a surge in agreements between universities and foreign enterprises. For instance, several Japanese and European firms have recently commissioned research in American laboratories. And many large

companies have invested in innovative small foreign firms to obtain access to technology and know-how. For small and medium-sized countries in particular, strategic international partnering is the way of the future. It promises to reduce the risk and broaden the effectiveness of investment in S&T.

This rapidly emerging internationalization poses a problem for governments in their crafting of a national S&T strategy: should they support international research? Or should they concentrate on national research and the identification of priorities for collaboration? A driving force in their crafting of a national S&T strategy is the growing potential from combining different technologies and building on interdisciplinary cross-fertilization.

Regionalization, selectivity, and concentration

Since the early 1980s, many advanced countries and their regional governments have focused on S&T as a driving force for regional development. The proliferation of science parks and incubator malls shows how popular this regionalization trend has become. So does the intense interregional competition for private- or public-sector research laboratories and technology centres; many communities seek to emulate the familiar American technology-oriented industrial complexes. Perhaps the most ambitious of all S&T regionalization efforts is Japan's Technopolis program, which involves major universities in 25 regions.¹⁵ But regional pressures can lead to duplication, lack of coordination, and poor selectivity. Regional procurement similarly can contribute to balkanization of the S&T infrastructure and can dilute scarce S&T skills.

The pressure of the technology race, the widening horizons opened by S&T advances, and the rapidly rising cost of R&D have together forced virtually all advanced countries to become more selective in the allocation of R&D resources.¹⁶ Each inevitably confronts the need to choose priorities. It is here that Japanese efforts proved so fruitful. Major efforts at concentration have focused on the information technologies in particular — the European ESPRIT program, Japan's Fifth Generation Computer program, and the British Alvey program.¹⁷

In choosing priorities there is growing attention to how public programs support and complement private R&D, and to identifying areas of science in which public support might reasonably produce results that lead to profitable products and processes.

Public support cannot make good the deficiencies of private spending. But it can, with judicious choice of targets, help the private sector help itself. So can imaginative use of government procurement, by identifying long-term needs and specifying performance generally rather than detailed designs.

The S&T systems of advanced industrial countries are being pressed by government policies to concentrate resources and to build on strengths, promote excellence, encourage collaboration, achieve critical mass, and make the best use of expensive equipment. Policies for collaboration, selectivity, and concentration require careful balancing and coordination with those designed to ensure adequate competition.

Technology transfer, inflow, and diffusion

Most industrial countries generate only a small part of the technology they use — from one twentieth to a fiftieth for most advanced countries other than the United States or Japan. Yet advanced industrial countries have historically promoted the development of technology, when it is really the rapid adoption of the new technologies that generates most economic benefit. In practice, development and diffusion of technology are complementary; policies to reinforce their effects need to be integrated.¹⁸

Foreign technology is not, however, free. Normally it is acquired through fees, licences, or joint-development arrangements. In some cases it can only be obtained in return for proprietary technology. Frequently, also, such technology complements rather than replaces domestic R&D. For instance, whether small and medium-sized enterprises can assimilate external technology depends largely on their in-house technical expertise.¹⁹

In recent years more attention has been paid to tapping the international pool of scientific knowledge, improving its inward flow, and speeding the diffusion and adoption of technology. Many countries have addressed the many macro-level and company-level factors that bear on the problem of the slow, piecemeal diffusion of information technologies.²⁰ They range from aggregate demand and the labour markets to regulations and standards, size of firms, and the availability and cost of financing. Standards affect compatibility among the computer software, services, and hardware in integrated production systems and are therefore of central importance in influencing the diffusion of products and services.

Two widely observed key failings are the shortage of personnel with the technical skills to evaluate and apply new technologies, particularly among small and medium-sized firms, and the sparsity of the type of organization that would make adoption speedy and effective.

At the same time there has been growing concern over how to improve the transfer of technology with commercial potential out of government labs and universities. The result has been a proliferation of offices and programs to this end as countries strive to diversify into high-value-added products and to be early and sophisticated users of advanced production technologies.

Promotion and adjustment

The current reality is that all advanced industrial countries have crafted S&T policies and strategies to succour their own, some more overtly than others. Countries such as France, the United Kingdom, and the United States have focused their efforts mainly on high-technology industries through R&D support, government procurement, regulation, and subsidies. Their strategies tend to be mission-oriented, focused on major projects, and in some cases led by defence procurement. The strategies of others, such as Austria, Sweden, Switzerland, and West Germany, aim more at diffusion and are concerned less with developing cutting-edge technologies than with strengthening mechanisms for technology transfer and upgrading the capacity of firms to adopt and adapt new technologies.

A crude distinction may also be made in national policies and strategies of adjustment to new technological opportunities. Some countries, particularly the United States, emphasize shifting resources from old to new industries and working at the cutting edge of entirely new technologies. In others, a prime example being West Germany, the emphasis is on expanding capability, building on skills and resources that are highly industry-specific, and perfecting existing technologies.

National methods of promoting technology development are quite varied. Table 3 shows that they differ in reliance on industry-specific measures, centralization within government, and the role of defence spending. The indications are that technology policies do matter and that their effect overwhelmingly depends on the environment in which they operate.²¹

Many evaluations have been made of international experience in crafting and implementing strategies. Lessons are, however, only

Table 3. Technology Policy in Five Industrial Countries.

	Reliance on industry- specific measures	Centralization within government	Reliance on defence spending
France	high	high	high
Japan	high	high	low
United Kingdom	medium	low-medium	medium
United States	low	low	high
West Germany	low-medium	medium	low

Source: United States of America, Office of Technology Assessment, *International Competition in Services* (Washington, D.C., 1987).

cautiously drawn from this experience, for each country differs in its ideologies, institutional structures, social arrangements, stage of technological evolution, pattern of specialization, economic size, and emphasis between technology development and diffusion. Lessons appropriate for one country may not be so for another; however, those that appear reasonably compelling are that:²²

- S&T policies warrant attention at the highest levels of government;
- The astute policymaker requires a firm grasp of the changing technological environment;
- Expectations of national economic benefit from S&T have increased rapidly but may be misplaced if investment is poorly directed;
- The ability to do first-rate scientific research does not necessarily have a strong association with the pace of economic growth in leading countries;
- The capacity to perform applied R&D depends critically on knowledge that can be obtained only through doing basic research;
- Economic resilience probably will require a broad basic research capability, in view of the wide uncertainty about which are the next areas of science likely to underpin important new technology;
- Many countries are now stressing R&D in the new generic technologies that are emerging, realizing that major industries are becoming more science-dependent;
- Success in S&T, especially in small and medium-sized countries, increasingly demands cooperation between universities, industry, and government;

- Governments are particularly encouraging collaborative, pre-competitive research to develop generic technology, while shifting from support of short-term development;
- The international network of R&D and technological systems means that national systems of S&T, to be healthy, need careful management of the international connection;
- There is no single, simple blueprint for success in technologically uncertain markets;
- Technology policy is most effective when matched with an overall industrial and economic policy that, among other things, reduces uncertainty and coordinates policies for investment, taxes, education, training, regulation, competition, and interest rates;
- A climate conducive to innovation includes incentives that stimulate private investment in R&D to adequate levels;
- Governments can assist industry by mobilizing the S&T community to chart future directions for emerging technology. This results in a grassroots forecast at moderate cost;
- Far more is technically feasible than is profitable, let alone acceptable or desirable, and all these considerations bear on forecasting;
- Neither science-push nor demand-pull is universally applicable in innovation and technological change. Between the two there is much interaction and variation between sectors, products, and technologies;
- Technological advance is highly complex and strikingly different between industries. Hence the most appropriate climate for innovation and its technological instruments depend on what sectoral impact government seeks;
- In shaping standards there is a dilemma: policy intervention is most effective at the beginning of technological evolution, just when public agencies, perhaps inevitably, know least about the technology;
- The development of technological opportunities in a range of industrial sectors requires a high level of R&D intensity in each of those sectors. There are also other requirements in marketing, communication, management skills, infrastructure facilities, and entrepreneurial activity generally;
- Technology diffusion mechanisms must be proactive and seek out industry;

- A key factor in the rapid and effective diffusion of technology is a well-educated labour force;
- Governments must particularly attend to the needs of small and medium-sized enterprises and the innovative contributions they may be able to make;
- Stimulating technical innovation in small and medium-sized countries often requires associated social and institutional innovations;
- Governments must establish an infrastructure for S&T-driven innovation, in particular by appropriately regulating telecommunications;
- In terms of product development cycles, the thrust of supply-side support by governments, under the pressure of emerging and expected international agreements on trade, is shifting from the expensive end of industry policy, such as subsidies for modernization and expansion schemes, to the relatively cheaper end of research and innovation policy.

Government has many acceptable and valid reasons for intervention, at national and regional levels; these reasons range from failure of the market mechanism to military requirements. Countries that lack size and resources are, in effect, forced to make choices; in particular they have to seek niches — in electronics for instance. Large countries can more readily afford to “let a thousand flowers bloom.”²³

Governments have to recognize that what is conducive to corporate competitiveness is not necessarily conducive to national competitiveness. Firms may indeed benefit substantially from subsidies to R&D, to innovation, or to management and technical training, but they may exploit the resulting competitiveness by producing outside the home country.²⁴

Chapter 3

How Are We Doing?

Riding the rollercoaster

How well are we doing? The answer depends on the indicators we choose and the way we look at them. In economic performance, Canada seems to be doing exceedingly well. But there are signs that the economy may not be as robust as first indications suggest. Economic growth per person was considerably higher in 1985 in Canada than in the rest of the industrial world. In 1986 it slipped to about average, but Canadian output and employment grew fastest of any of the major industrial countries. In 1987 Canada's inflation-adjusted growth in gross domestic product (GDP) was third among the seven most industrialized countries. Since 1980 our economic growth has been a distant second to Japan's, and growth per person was third, behind that of Japan and the United Kingdom. Our growth rate in jobs was also third, behind Australia and the United States. In 1988 Canada's long, strong economic recovery since the 1982 recession continued in its sixth year. The business mood was one of cautious optimism.

Overall, Canadian economic performance in recent years was not so bad. But neither was it very good. More important is the perception of Canada's leaders, revealed at a 1988 national conference on technology and innovation, that Canadian performance is a long way from the level required reasonably to ensure that our standard of living does not become lower than those of other developed countries.

Recently our manufacturing output has been running at about 82 per cent of capacity, a far cry from the 69 per cent of the 1982 recession. Moreover, higher profits and a need for more capacity are contributing to a surge in new business investment. As demand picked up after the 1982 recession, output bumped up against factory capacity; following a long chill, investment began to revive in 1985. By 1988 it was in full swing, after some hesitation in 1986 following a slump in spending on energy when oil prices plunged. With some commodity prices rising, profits rebounded in 1987 and early 1988 to stimulate investment. In 1988 there was a major rise in capital-spending plans — a promising sign, in that spending on machinery and equipment is essential to improving productivity. Canada also led the world in 1986 in putting up new equity

capital, which means risk capital rather than debt. Almost half the equity issues were for small business.

The bad news is that ours is still a rollercoaster economy, the worst hit by the 1982 recession and then surging back to prosperity. Our mountain of foreign debt reveals we are living way beyond our means, with borrowing abroad supporting high consumer spending. Moreover, we still stand a low fifth among the main industrialized countries in such key indicators as rate of unemployment (1986), consumer-price inflation, and productivity growth in real gross national product (GNP) per employed worker. Also, during 1980-85 we had an abysmally low 1.1 per cent growth in total factor productivity. And that was despite 6.6 per cent growth in the measured domestic R&D capital stock, which is a measure of cumulative industrial R&D investments adjusted downward for obsolescence in the value of knowledge developed through R&D activities. The stock includes current intramural R&D expenditures, extramural R&D payments, and extramural payments for technology. Between 1977 and 1986, Canada's manufacturing sector recorded the slowest productivity growth of the 12 most industrially developed nations. In 1986 it was the only one with a loss in productivity. Canadian industry has been very cautious about investing in productivity-improving technology.¹ Although Canada has created more net new jobs in the past three years than the 12 nations of the European Economic Community combined have in the past 15 years, much of the small-business job boom has been in the low-productivity service sector.² Thus Canada's labour productivity record has been poor. Furthermore, economic recovery has been distressingly uneven across the country; it has fuelled a feast for Ontario and Quebec but is a long time coming for Atlantic and Western Canada. The jobless rate in much of 1988 was at its lowest level since the recession, but still has not gone below 7 per cent for the past dozen years, a tragedy and waste that leaves the federal government with a major problem.

Foreign events are far more significant for Canada's economic performance than they are for most industrialized countries. Canada exports about 30 per cent of the goods and services it produces, with 77 per cent of exports going to the United States. Most of our exports are raw and semiprocessed resources and automotive products, although manufactured exports, particularly transport equipment, have become more important (Table 4). This dependence on other countries heightens the pressure on governments to cushion temporary shocks on people,

Table 4. Commodity Distribution of Canadian Exports, 1960 to 1985 (percentages).

	1960-70	1970-80	1980-85	1985
Exports of goods and services (as a proportion of GNP)	18.8	23.4	26.9	29.9
Distribution:				
Merchandise	78.9	81.7	82.5	84.1
Agricultural products	8.2	5.4	5.7	4.1
Mining products	12.1	10.7	6.0	6.0
Manufactured goods	54.3	63.4	69.5	72.3
Durables	31.0	42.9	47.3	53.1
Wood and lumber	6.1	4.5	4.5	3.6
Iron and steel and non-ferrous metals	11.3	7.1	6.2	6.3
Machinery and equipment	4.2	5.9	8.2	8.1
Transportation and equipment	8.2	23.6	26.5	33.3
Nondurables	23.3	20.5	22.2	19.2
Food and beverages	5.1	3.8	4.1	3.6
Paper and allied products	12.8	9.2	7.7	6.5
Services	24.4	18.3	16.6	14.3
Investment income	3.9	4.1	4.6	4.5
Other services	5.1	4.5	4.4	3.8
Travel	7.7	4.9	3.8	3.2
Total^a	100.0	100.0	100.0	100.0

^a Sums of components do not add up to totals because (a) freight and shipping services are excluded in the case of services as are balance-of-payments adjustments in the case of total goods and services, and (b) statistical gathering methods were not consistent.

Source: R. Voyer and E. Miller, "Canada in the World: The Competitive Challenge," paper presented at the National Conference on Technology and Innovation, organized by the Government of Canada, Toronto, 13-15 January 1988.

industries, and regions, to capitalize on development opportunities, and to maintain access to foreign markets.

Satisfaction with current performance has to be tempered, therefore, by concerns about long-term trends and prospects such as, for instance, an appreciation of the Canadian dollar against the American. Many

Canadian exports, particularly resources, compete on price. The concern when the Canadian dollar strengthens is "if our exports are selling only because they are cheap; if we can't succeed also because of quality, service and innovation, we are in real trouble."³ Other countries, particularly Japan, manage to keep exporting despite a huge appreciation in their currency. Can Canada do the same?

Resource exports are vulnerable both to protectionism in major markets and to new technologies that can replace Canadian materials, thereby reducing demand. These growing dangers provide the impetus to diversify, to build new foundations for industrial strength through innovation, particularly in Northern Ontario and Quebec as well as Atlantic and Western Canada. The status quo is not good enough.

Current good performance must not spawn expectations of continued wealth from "business as usual." Even without ratification of the free trade agreement, it would not have been business as usual. Canada could become the poor cousin in the industrial world. Catching up will be tough when we start with rates of manufacturing productivity 30 per cent below those of our major trading partner and with an R&D base feeble in the global scale of comparison.

Structural change and technology trade

Canadian jobs are increasingly to be found in the service sector and in medium-technology industries. As the service sector has accounted for a greater share of production and employment over the past two decades, so the share of manufacturing has fallen. Manufacturing production dropped from 23 per cent of GDP in 1970 to 21 per cent in the mid-1980s. The dip in the employment share was greater, from 23 per cent to 19 per cent.

This pattern is common in advanced industrial countries; there is a growing similarity in their broad production structures, though not in their patterns of specialization. In past decades Canada has been increasing its specialization in paper and wood products.

Since 1970 Canada has been shifting out of low-technology industries into medium-technology industries, a group dominated by transport equipment but also including chemicals, rubber and plastics, non-ferrous metals, and some types of machinery. (Medium-technology industries in the main industrial countries are those whose R&D expenditure averages about 1 per cent to 3 per cent of value added.) As Table 1 (p. 25) shows, the share of manufacturing output by these

industries in Canada rose 3.8 per cent between 1970 and 1983. By contrast the share of the high-technology group dropped 1.5 per cent and the low-technology group 2.3 per cent. Over the same period, the export share of the medium-technology group rose 0.5 per cent, and that of the low-technology group dropped 3.6 per cent. Contrast that with the import scene. The high-technology group's import share rose 4.1 per cent, the medium-technology group's rose 1.1 per cent, and the low-technology group's dropped 5.2 per cent.

These figures indicate a large Canadian trade deficit in high technology. However, figures based on a narrower definition of high technology reveal a smaller deficit — more than \$7 billion in 1987, against more than \$13 billion using the broader definition. The relationship of exports to imports was relatively stable in the 1980s.

Innovation and technology diffusion

Canada, for reasons that include ample natural resources, significant foreign ownership of industry, limited access to foreign markets, and rather small firms, has not seen technological innovation as a strong card.⁴ Typically, Canada nestles in the middle of the pack of 22 advanced countries when ranked on capacity to innovate.⁵ Canada's generally weak international status in innovation is revealed by various indicators. These include business spending on R&D, total spending on R&D, anticipated R&D spending, private funding of business enterprise R&D, growth in business enterprise R&D expenditure, total and industry R&D personnel, adequacy of patent protection, patents granted to residents, patents awarded to non-residents compared to residents, securing of production rights abroad, and company efficiency in scanning new technologies. Trends in technology and global markets make Canada's lethargy unacceptable if Canadians wish to maintain their high standard of living.

How are we doing in adopting technologies? Not well. And that perception has fuelled the proliferation of technology centres and programs of technology inflow. But the data available on international levels of diffusion of important new technologies are, unfortunately, poor. What evidence there is — on robot technology, automated inspection and quality control, automated materials handling, and microelectronics in process applications — suggests a gap in adoption levels between Canada and other advanced industrial countries. Despite technological strengths in development and adoption, notably in

telecommunications and agriculture, the majority of Canadian firms are perceived to have done poorly in adopting innovative technology and practices. As the Economic Council of Canada recently reported:

Canada's persistent lag in the introduction and use of computer-based technologies is an urgent national problem of major proportions. The diffusion of process technologies is too slow. The capital investment needed for the introduction of advanced equipment is also lagging seriously. Without that spending, process automation just cannot take place.⁶

The Economic Council argues that the gap is much larger and more serious than first appears, because even where the new technology is belatedly introduced, it is often not fully exploited because of inadequately trained workers and poor integration with the whole production system. Whether the latest surge in business investment will satisfactorily close the gap and hasten the learning process remains to be seen. Investing in modern equipment is not in itself enough. It is critical to use it effectively.

Yet a word of caution. Underuse of advanced manufacturing technologies in some Canadian sectors may largely reflect the average size of firms.⁷ Where small firms predominate, as is often the case in Canada, the complex manufacturing technologies that require long production runs to offset their high cost are not necessarily suitable. Fast adoption does not always mean effective assimilation, any more than slow adoption means sub-optimum use.

In this light, Table 5, which shows 1986 shipments that used particular advanced technologies, presents more questions than answers, an agenda for research. In the survey on which the table is based, respondents accounted for 51 per cent of the estimated value of 1986 Canadian manufacturing shipments. Although the data improve our knowledge of the diffusion of some important new technologies into Canadian industry, they do not answer the policy question of whether the pace of diffusion is too slow — or too fast — and whether a firm has benefited from adopting or sometimes adapting the technology.⁸

GERD and industrial R&D

International comparisons help illuminate, but not resolve, difficult questions about whether Canada spends enough on R&D.⁹ They indicate a low Canadian performance of R&D despite rapid improvements in the late 1970s and early 1980s. Since 1982 the level of

Table 5. Percentage of 1986 Shipments from Responding Manufacturing Establishments that Came from Establishments Using Defined Technologies.

	Design and engineering ^a			Fabrication and assembly ^b					
	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	2.6
Food, beverages, tobacco	16	8	10	16	16	17	6	11	9
Rubber and plastics	47	19	23	16	17	10	3	14	8
Leather, textiles, clothing	32	13	9	21	18	13	1	3	2
Wood	19	21	15	21	17	17	10	6	2
Furniture and fixtures	12	4	4	23	5	7	4	9	8
Paper and allied products	30	12	13	22	9	5	4	10	2
Printing, publishing, and allied activities	16	11	12	19	6	8	8	1	Neg
Primary metal	64	34	17	52	41	19	15	31	34
Fabricated metal products	35	23	15	42	19	17	5	10	8
Machinery	52	28	24	72	16	18	11	10	23
Transportation equipment	60	37	33	48	32	28	20	69	76
Electrical and electronic products	61	37	34	42	33	24	17	29	11
Non-metallic mineral products	22	8	7	26	15	15	2	19	6
Petroleum and chemicals	46	3	21	7	8	4	1	14	3
Other manufacturing	27	10	3	22	14	5	1	14	8
All manufacturing	41	19	19	30	20	16	9	26	23

Table 5: (continued)

	Automated material handling^c		Inspection, sensor and testing equipment^d		Communications and control^e				
	3.1	3.2	4.1	4.2	5.1	5.2	5.3	5.4	5.5
Food, beverages, tobacco	11	4	30	25	16	18	17	51	28
Rubber and plastics	6	6	44	31	48	50	43	64	50
Leather, textiles, clothing	6	4	19	14	22	23	21	28	27
Wood	17	5	31	21	18	15	17	18	39
Furniture and fixtures	x	x	2	x	11	15	18	17	13
Paper and allied products	14	7	59	48	31	33	30	69	62
Printing, publishing, and allied activities	7	5	15	x	23	16	15	29	21
Primary metal	37	5	72	52	68	62	43	89	83
Fabricated metal products	7	5	28	22	20	26	24	46	29
Machinery	11	3	22	30	27	20	27	49	23
Transportation equipment	29	53	86	87	40	58	84	92	72
Electrical and electronic products	12	7	58	59	52	37	32	54	42
Non-metallic mineral products	13	9	40	19	27	31	20	60	35
Petroleum and chemicals	7	1	45	50	43	42	46	74	59
Other manufacturing	x	x	31	28	19	21	18	37	22
All manufacturing	16	15	50	46	34	38	41	66	51

Table 5: (continued)

- ^a Design and engineering
 - 1.1 Computer-aided design (CAD) and/or computer-aided engineering
 - 1.2 CAD output to control manufacturing machines
 - 1.3 Digital data representation of CAD output used in procurement activities
- ^b Fabrication and assembly
 - 2.1 Standalone number-controlled or computer number-controlled
 - 2.2 Flexible manufacturing cells
 - 2.3 Flexible manufacturing systems
 - 2.4 Laser-based fabrication equipment
 - 2.5 Simple pick and place robots
 - 2.6 More complex robots
- ^c Automated material handling
 - 3.1 Automated storage and retrieval systems
 - 3.2 Automated guided vehicle systems
- ^d Inspection, sensor, and testing equipment
 - 4.1 Performed in process
 - 4.2 Performed on the final product
- ^e Communications and control
 - 5.1 Local area network for technical data
 - 5.2 Local area network for factory use
 - 5.3 Intercompany computer network linking plant to suppliers and/or customers
 - 5.4 Programmable controllers
 - 5.5 Industrial computers used for control on the factory floor

x = data confidential.

Neg = Negligible. Amount too small to be expressed.

Source: Statistics Canada, *Survey of Manufacturing Technology*, Summary Report (Ottawa, June 1987).

gross expenditures on R&D (GERD) has hovered around 1.4 per cent of GDP. That is way below the 2.9 per cent in the United States and the 2.0 to 2.6 per cent in France, Japan, the Netherlands, Sweden, the United Kingdom, and West Germany during the mid-1980s. Yet the spending by Canadian governments on R&D is not out of line with that of many other countries. However, in the mid-1980s government performance of defence R&D in Canada (0.05 per cent of GERD/GDP) bore no comparison with equivalents in countries such as the United States (0.88 per cent), United Kingdom (0.66 per cent), France (0.46 per cent) and Sweden (0.28 per cent) and was barely half the equivalent of those in West Germany (0.11 per cent).

The key difference in overall national R&D performance is the low level of R&D spending by industry in Canada (Table 6). Canadian industry now accounts for about 50 per cent of GERD. That is certainly much higher than the 36 per cent prevalent in the mid-1970s, but is still far below the level of other major industrial countries. Canada's low level of industrial R&D is partly explained by structural differences, such as the relative smallness of Canadian firms, our resource-oriented industry, and high level of foreign ownership, as well as limited access to major markets and relatively low level of government support.¹⁰

A growing number of Canadians, including Prime Minister Brian Mulroney, are deeply perturbed by this.¹¹ Like the Science Council, they view R&D as the lifeblood of a successful economy. They consider that the industrial demand for R&D must increase if Canada is to move into more-knowledge-intensive industries and sustain its living standards. As the Canadian Manufacturers' Association has commented, the lack of industrial R&D by Canadian industry is "a clear indication that CEOs in many Canadian companies are not measuring up to what is required in today's competitive environment."¹² The direct and indirect connections of R&D to productivity are becoming better understood; R&D and adopted technology complement rather than substitute for each other.¹³ It should be emphasized, however, that competing on technology involves more than increasing industrial R&D. Equally crucial is a well-managed, productive relationship between industrial R&D and marketing.¹⁴

In Canada, 25 firms perform more than half the industrial R&D, but only three spend more than \$100 million a year on it. Canada lacks R&D-based, medium-sized to large, world-class firms. Among manufacturing industries in 1985, self-funded, current R&D expenditures

Table 6. R&D as a Percentage of Gross Domestic Product, for the 12 Largest Economies in the Organization for Economic Cooperation and Development (1986 or latest year).

Country	Total R&D	Industry	University	Government
United States	2.89	2.07	0.39	0.34
Japan	2.81	1.88	0.57	0.28
Sweden	2.79	1.97	0.69	0.12
West Germany	2.66	1.92	0.40	0.33
France	2.38	1.40	0.37	0.60
United Kingdom	2.33	1.47	0.32	0.46
Switzerland	2.28	1.69	0.40	0.13
Netherlands	2.06	1.16	0.47	0.38
Italy	1.47	0.85	0.28	0.35
Canada	1.35	0.68	0.32	0.32
Australia	1.14	0.39	0.30	0.44
Spain	0.48	0.28	0.08	0.12

Sources: OECD, "Selected Science and Technology Indicators, Recent Results"; and special Statistics Canada tabulations. Reported in Government of Ontario, *A Commitment to Research and Development: An Action Plan* (November 1987).

averaged 1.3 per cent of sales. The highest percentages were in telecommunications equipment (13.4), aircraft and parts (10.1), other electronic equipment (7.3), electronic components and parts (4.9), and drugs and medicines (4.0). Industrial R&D is heavily concentrated, with Ontario accounting for \$1.6 billion and Quebec \$0.6 billion of the \$2.7 billion spent by business in 1985.

An alternative view of concentration is provided by estimates of Canada's industrial R&D capital stock. Provisional estimates for 1987 reveal the total industrial R&D capital stock to be \$7.89 billion. The four leading industries, aircraft (\$1.07 billion), telecommunications equipment (\$1.03 billion), business machines (\$0.82 billion), and petroleum products (\$0.78 billion), account for close to half the total (Table 7).

The pace of annual growth in the stock causes concern. In the early 1980s it more than doubled, from 4 per cent in 1980 to a peak of 9 per cent in 1984. But then the pace of growth slowed, to an estimated 5 per cent in 1987.

In recent years it was not necessarily the hi-tech sectors that led the way. The industries adding most rapidly to their industrial R&D capital

Table 7. R&D Capital Stock, 1981 to 1987 (1981 \$ 000 000).

Industry	1981	1982	1983	1984	1985	1986^a	1987^a
Food, beverages, tobacco	216.5	233.9	248.8	284.5	339.7	398.5	412.0
Rubber and plastic products	135.4	146.2	139.4	135.3	132.4	122.6	113.8
Textiles	48.8	50.1	51.9	55.3	59.0	60.0	61.9
Wood	24.5	33.2	42.5	49.7	53.2	55.6	60.1
Pulp and paper	242.0	252.6	265.6	278.4	282.4	283.4	289.4
Ferrous primary metals	109.7	110.5	113.8	115.1	111.6	110.2	110.6
Non-ferrous primary metals	385.6	379.1	374.2	368.2	356.6	342.1	335.4
Metal fabricating	112.9	114.1	116.1	119.3	122.6	124.6	120.9
Machinery	257.4	261.0	269.1	285.8	302.5	312.9	315.1
Aircraft	647.6	709.8	767.0	875.1	1039.2	983.6	1066.1
Other transportation equipment	219.4	226.4	237.0	257.4	275.9	310.0	328.2
Telecommunications equipment	466.2	521.2	602.5	680.2	784.4	893.3	1029.4
Electronic parts and components	109.1	103.2	96.9	102.3	119.0	129.9	139.8
Other electronic equipment	123.9	128.4	140.3	160.0	197.9	236.7	279.4
Business machines	432.3	479.0	565.9	617.0	691.7	763.5	816.6
Other electrical equipment	282.6	290.8	307.8	335.2	363.0	385.5	396.9
Non-metallic mineral products	67.0	66.4	67.5	69.0	69.5	69.8	72.8
Petroleum and coal products	488.9	527.9	614.7	765.1	805.1	794.0	781.7
Drugs and medicines	220.2	221.4	227.0	234.5	251.6	271.5	293.2
Other chemical products	465.7	496.1	525.3	555.3	599.0	634.3	673.2
Scientific and professional equipment	97.4	106.0	114.7	116.0	115.2	115.7	120.4
Other manufacturing industries	39.1	36.9	37.6	50.9	63.0	69.9	77.7
All manufacturing industries	5192.2	5494.2	5925.6	6509.6	7078.9	7523.2	7894.6

^a Preliminary figures.

Source: Statistics Canada, Science, Technology and Capital Stock Division, "A Note on R&D-Capital Stock Estimates" (Ottawa, November 1987), 18.

stock during the three years 1984-87 were other electronic equipment (75 per cent), other manufacturing (53 per cent), telecommunications equipment (51 per cent), food, beverages, and tobacco (45 per cent), electronic parts and components (37 per cent), and business machines (32 per cent). Still, our leading strength stands out. Of the estimated \$1.385 billion addition to the nation's industrial R&D capital stock in those same three years, telecommunications equipment alone accounts for \$349.2 million. Of the other three leaders, aircraft added \$191 million and business machines added \$199.6 million, but the R&D capital stock of petroleum and coal products dropped by \$16.6 million.

In 1985 companies that performed R&D funded 69 per cent of it themselves. The federal government funded 11 per cent, excluding tax incentives. Other Canadian sources, including provincial governments (\$43 million), accounted for 11 per cent, and the rest came from foreign sources. The main federal government support went to the aircraft and parts industry (\$100 million).¹⁵ Claims for investment tax credits for industrial R&D rose from less than 5 per cent of Canadian industrial R&D expenditures in 1978 to more than 15 per cent by 1984. The abrupt jump in the mid-1980s reflected the federal government's badly flawed and expensive experiment with the Scientific Research Tax Credit.

Industrial R&D spillovers

According to studies for the Science Council of Canada, the private rate of return to industry from R&D spending is considerably higher than the return on equivalent capital investment.¹⁶ However, R&D efforts often tend to spill freely over to other firms, who thus reduce their own production costs and generate extra revenues. This raises the social rate of return above the private rate. R&D spillovers may be both intra-industry and inter-industry. They allow a firm to benefit from the R&D of other firms, a form of diffusion that transmits benefits freely through the economy. Because they lead to a divergence between the private and social rates of return to R&D capital, they could be considered a source of market failure.

Earlier estimates are that for 1981 the social rate of return for Canadian industries with high R&D spending was about 115 per cent of the private rate. In industries with lower R&D spending, the social rate was nearly 170 per cent of the private one. The extent of divergence is thus one indicator of underinvestment in R&D capital in the economy. The estimates also suggest that in the industries with high R&D

spending, intra-industry spillovers are complementary, actually increasing total R&D. In effect, firms in those industries cannot only adopt technology; to benefit from spillovers, they must also do their own R&D; acquiring and developing technology are complementary activities. Thus Canada cannot fully compensate for its lack of industrial R&D by simply purchasing and importing more technology.

Recent work for the Science Council identifies the industries within which large spillovers and social returns occur. This indicates where investment in R&D capital is lower than the social optimum.¹⁷ The analysis focuses on the nine major industries performing R&D between 1963 and 1983. It shows that, in five of the nine, the social rates of return are at least twice the private rates. In nonelectrical machinery they are six times higher, and two other industries — petroleum and chemicals — are major sources of inter-industry R&D spillovers. Smaller sources are primary metals and the rubber and plastics industries. The work also shows that private rates of return, which range from about 25 per cent to 40 per cent annually, are not necessarily higher for industries that generate the spillovers. The industries that are major beneficiaries of inter-industry spillovers — primary metals, metal fabricating, nonelectrical machinery, transportation, electrical products, and petroleum products — are not often themselves major sources of spillovers.

These and other indicators, plus the assessment of major trends in technology development and international competition, convincingly support other arguments for raising the level of Canadian industrial R&D substantially and creating a more technologically sophisticated society. But within what policy framework? At what level of priority? With which institutional mechanisms?

Chapter 4

Filling the Vacuum: Policy and Strategy

National S&T policy and the Council of S&T Ministers

In 1987 for the first time a Canadian prime minister identified the fundamental Canadian challenge as the need to meet new international competition and to use science and technology to strengthen Canadian competitive advantage.¹ He concluded, moreover, that the key need is for the private sector to do more R&D and to be responsible for a greater share of the national S&T effort. This is a far cry from the lost decade of the 1970s, when the Science Council was a lonely voice promoting just such a focus,² and a big step from the early 1980s when Canadian governments pursued development through major resource projects.

Before Canada could address the fundamental challenge identified by the prime minister, there needed to be principles that would govern investment in S&T and fill what the Science Council has frequently noted to be a serious policy void. Such principles were already being sought when the prime minister made his statement. There had been a dialogue with stakeholders, which included an attempt by the Science Council to generate consensus at a national meeting of business, labour, and governments in Winnipeg in 1986, and two years of intensive negotiations between federal, provincial, and territorial governments.³ In March 1987 these governments jointly announced Canada's first national science and technology policy. It is an important achievement, a collective commitment to marshalling Canada's S&T resources in the service of regional economic and social development. The broad objectives endorsed by each government cover technology diffusion, industrial innovation, strategic technologies, basic and applied R&D, and a supply of the necessary highly qualified people. Short in detail and long on promise, it nevertheless finally provides the basis for concrete action.

In adopting the policy, the governments also agreed on a continuing forum, the Council of S&T Ministers, to monitor progress toward the policy's objectives. The Council in turn established federal-provincial working groups to put forward suitable proposals, such as how to

increase industrial R&D, apply strategic technologies in the resource sector, and use S&T to support regional development.

The rhetoric of good intentions is encouraging. But how about the priorities, the mechanisms, and the concrete actions?

NABST and ISTC: convictions and mechanisms

In 1987 the prime minister rightly argued that Canadians had relegated R&D to a peripheral role in national life, when in fact it is the cornerstone of great future endeavour.⁴ His government has placed it (in word, though not fully in deed) at the top of the national agenda, as witness the formation of a National Advisory Board on Science and Technology (NABST), chaired by the prime minister and including the ministers of finance, industry, and science. That should set S&T at the very centre of the public policy process in Ottawa, a place that the Science Council has long argued it warranted. The prime minister's role should ensure that decisions on S&T priorities are based on private-sector, political, and bureaucratic expert opinion. It raises expectations that deeds will follow rhetoric and that money will be found.

A further measure of this new priority is the rhetoric of the finance minister. He seems convinced of the importance of the new technologies in honing competitiveness and maintaining economic growth. His recent support elevates new technologies to the level of issues such as free trade and tax reform.⁵

Further evidence is a departmental reorganization in the federal government. The new department known as Industry, Science and Technology Canada (ISTC) is intended to be the federal flagship for economic development. It will ensure effective integration of advanced technology and competitive industrial capacity and promote increased industry spending on R&D. The task is daunting, given recent bureaucratic history and the challenge of inspiring new industrial thought.

Over recent years the Department of Regional Industrial Expansion (DRIE) has badly diluted its sectoral expertise. The private sector felt its grass-roots needs were not served well by the department. DRIE's major policy instrument, the Industrial and Regional Development Program, was increasingly seen to have failed to achieve the two somewhat conflicting objectives of promoting industrial growth and redressing regional disparity. The auditor-general in 1987 considered that poor

project screening was a problem. The department was confused about its direction and had lost its motivation.

In late 1986 and early 1987 the government attempted, first, to make DRIE more outward-looking and active, working with customers to solve their growth and competitiveness problems, second, to concentrate on priorities, rather than responding to pressure on program and operating budgets, and third, to integrate its efforts more closely with provinces and other government departments.⁶

In mid-1987 the federal government merged the DRIE industry functions with the Ministry of State for Science and Technology to form ISTC. Thus S&T, previously served by a junior ministry, is now the responsibility of a senior government department with a powerful minister who sits on the federal cabinet's key planning and priorities committee.

This 1987 change in the former industry branches of DRIE attempts to strengthen their sectoral expertise by blending it with S&T capability. In particular there is emphasis on information and other enabling technologies.

These initial signals are positive. Yet substance is more important than structure. What is the new structure designed to do? The reorganization should result in far less propping up of old industries, mainly through capital grants, and more forward-looking support to back potential winners who develop or use new technologies. Programming should become more selective, unlike past programs that offered something for everyone and spread limited resources too thinly.

Another new departure by ISTC, considering long-term industry interests, is memoranda of understanding (MOUs).⁷ Under MOUs, government and industry cooperate on long-term goals, many of which are S&T-based. MOUs are signed by the department and either individual companies, usually large ones, or industry associations. They enable both parties to extend their horizons beyond dealing with immediate project-by-project issues and build commitment for long-range R&D investments and support. Thus, if successful they will help to create an S&T infrastructure through which Canadian industry can prosper. They will also become more important in that ISTC support can increasingly be aimed at the needs defined by stronger sector associations.

InnovAction

Pious words and the shuffling of bureaucracies will contribute little without concrete action and funding. The federal government has been constrained by lack of money. Nevertheless, in 1986 and early 1987 it took several actions. They include:

- Providing \$685 million to the granting councils to match private-sector funding of university research over five years;
- Providing up to \$7 million over four years to match private-sector contributions to the Canadian Institute for Advanced Research;
- Providing \$11 million a year to support biotechnology research in health, agriculture, food, cellulose, mining, and other areas;
- Providing \$824 million over five years to the Canadian space program;
- Agreeing with the government of Quebec to support jointly a new centre for optics research; and
- A variety of other S&T initiatives in partnership with provincial governments.

These actions were taken largely in isolation, without a coherent policy and clear sense of priorities; it was only in March 1987 that the federal government introduced its strategies for S&T — an action plan called InnovAction.⁸ InnovAction focuses on:

- Industrial innovation and technology transfer: Special attention is given to small business, acquiring technology from abroad, improving technology centres, and enhancing procurement;
- Strategic technologies: The plan particularly seeks increased support for generic applied research and new R&D partnerships, to broaden Canada's industrial base;
- Effective management of federal resources: The two main elements are to encourage private-sector investment in S&T through tax incentives, amended competition laws, better protection of intellectual property, and liberalized trade arrangements, and to ensure that federal S&T activities are related to major goals and, where appropriate, involve the private sector in setting priorities and sharing costs;

- S&T facilities and human resources: Emphasis is on providing adequate research facilities and helping the workforce adapt to technological change;
- Promotion of a science-oriented culture: The plan seeks to help Canadians appreciate the importance of technological innovation, creating a positive social environment for S&T.

These broadly based strategies draw on experience gained from widespread consultation and show that the government is committed to jointly devising measures to create wealth. They show a concern for user needs and envisage a strong role for the private sector within increased cooperation between industry, labour, universities, colleges, and government. The government's role is primarily as facilitator, except where it has a clear role in the promotion of health, safety, resource conservation, national security, and social and cultural goals.

But can the federal government deliver or does it really intend to? And even if it delivers, can these strategies succeed when they depend so heavily on inducements, incentives, and other forms of prodding the private sector? Have the private enterprise engines of Canada the real pulling and staying power, with government only as facilitator, to create wealth and sustain our standard of living in the new competitive environment?

Delivery: palliatives, but spending smarter

Since introducing InnovAction the federal government has announced several new initiatives. Those directly involving industrial technology development and application include:

- A management system through which industry-oriented federal laboratories will become more responsive to user needs;
- A technology outreach program (TOP) to consolidate and redirect the present \$17 million in federal assistance to technology centres outside the federal establishment that offer development and diffusion services;
- CAN-MATE (Canadian Manufacturing Advanced Technology Exchange), launched with the Canadian Manufacturers' Association, which will get \$3.5 million over seven years through the National Research Council. It will help Canadian manufacturers apply advanced technologies by fostering cooperation between

sectors, sharing information, monitoring developments, and defining and coordinating projects at the request of industry;

- An additional \$28 million over four years for the National Research Council's popular Industrial Research Assistance Program (IRAP) to help small firms acquire and use new technologies. That is close to a 10 per cent annual increase in funding;
- An additional \$18 million for university research, mostly to boost the matching funds that support the growing partnership between industry and universities;
- \$30 million over two years in new funding for the popular and successful Unsolicited Proposals Program, in which federal agencies and departments act as scientific authorities in sponsoring private-sector proposals. It has mostly supported small and medium-sized Canadian-owned firms;
- \$90 million to increase the ability of industry to develop and apply advanced microelectronics to products and processes. This program will also enhance cooperation between governments, universities, and industry and encourage complementary investments by provinces. The funding is not new money but a reorganization of existing resources. Available over four years, \$60 million will be allocated to ISTC's Microelectronics and Systems Integration Program. The other \$30 million, over three years, is available for research contracts with the Department of National Defence.

These initiatives are generally considered by the private sector to be helpful and well-conceived. But what do they add up to? Clearly, by the end of 1987, InnovAction was long on promise but short, though getting longer, on delivery. Most of the funding was smarter spending of existing resources. But new money was coming — about a mere \$100 million over four years. It is still too early to pass judgement, but it is hard not to conclude the emphasis was still on palliatives when the prognosis calls for more profound treatment. The pickings at that point were slim beside the \$1 billion in relief for western farmers, barely on a par with the controversial federal support promised for a new paper mill at Matane, Quebec, and way behind federal support for the Calgary Winter Olympics.

Then in early 1988 the stakes were raised considerably. An additional \$1.3 billion was announced for federal spending on science and technology over the following five years. How much of it will go

directly or indirectly to the development and diffusion of industrial technology remains unclear. It nevertheless can be expected to offset some of the estimated \$200 million a year lost as a result of various changes to the Investment Tax Credits program, to the rules for industry-performed-R&D tax credits, and to the rules for partnerships, which will probably lead to a reduction in venture capital. Has the right hand perhaps given a little more generously than the left has taken away? The signals remain mixed. Canada's level of public support for industrial R&D remains meagre compared with that of other countries. It is not surprising, then, that even with the prime minister as patron, the latest strategy is so far viewed as a long shot.⁹

Chapter 5

Three Major Issues: Taxes, Trade, and Regional Development

In 1988 three near-term issues dominated the development of industrial technology — tax reform, the free trade agreement (FTA) between Canada and the United States, and regional development. A fourth, how to strengthen industrial R&D and innovation, is the focus of the concluding section of this report.

Tax reform and R&D: a dampened climate and mixed signals

Background

Canadian governments have long promoted R&D in the private sector, primarily through grants and tax incentives. By 1982 this support was still a little higher through grants (\$240 million) than tax incentives (\$205 million). The balance between these two policy instruments has shifted over the decades, however, and the instruments themselves have been subject to numerous changes. In the decade since 1978 there have been four major changes in R&D tax instruments alone. Industry has not been able to rely on a consistent incentive policy.¹

Lack of formal public studies makes it difficult to assess the effectiveness of R&D tax incentives. But surveys and econometric studies do indicate that they have at least some effect,² in that by reducing taxes and increasing cash flow firms that do R&D can afford to do more.³ However, most firms do not take tax incentives into account explicitly in their R&D decision-making and budgeting. It is primarily the large, profitable firms that already perform R&D that are the main supporters of these tax incentives and that have been, until recent years, the chief beneficiaries from them.

Swedish experience with R&D tax incentives is of interest. In the past 20 years, Sweden has tried a variety of tax measures to encourage industry to increase its own R&D expenditures. Their poor results, as measured against the costs, persuaded the government to abandon them

in 1982, and since then Sweden's total industrial R&D has increased substantially.⁴ The experience suggests caution is needed in assessing the effectiveness of tax incentives.

Canadian experience is clouded by the innovative, but short-lived Scientific Research Tax Credit (SRTC), introduced in 1983 and cancelled in 1985. It provided substantial incentive for much-needed, upfront private investment in industrial R&D. It addressed many of the financing problems of small, innovative, technology-intensive firms, especially those not currently profitable. As an added benefit, it rapidly galvanized interest in R&D of a previously disinterested financial community. Unfortunately, the lack of proper checks and balances enabled the unscrupulous to profit without delivering intended R&D benefits.⁵ More than \$3 billion escaped government coffers, much of it for dubious or fraudulent research projects. The legacy has been far more caution in attracting risk capital to the support of R&D, if not a backlash against such R&D incentives. A certain nostalgia for the SRTC program remains, nevertheless, among many small, legitimate R&D performers.

Proposal

In June 1987 the federal government proposed comprehensive reforms to Canada's tax system. The broad intent was a fairer tax with lower rates on a broader tax base. The government proposed a first stage of reform, to personal and corporate income tax, to take effect in 1988, and a second stage, replacing the federal sales tax by a better system, after consultation with provincial governments and interested Canadians.

The government recognized that a more competitive world economy required a narrowing of the gap between Canada's corporate tax rates and those of other countries, especially the United States; otherwise Canada could lose jobs and investment opportunities. That was international economic reality. However, this country needed to balance its response to reality with concerns for fair distribution of income and the quality of life of its citizens.

Several points warrant emphasis with regard to the tax proposals and subsequent decisions. First, industry believes tax credits have helped substantially to increase industrial R&D. The level of R&D investment tax credits rose from \$857 million in 1977, when they were introduced, to \$3.6 billion in 1987, an average annual increase of more than 14 per cent. Over that period the number of firms claiming R&D tax credits increased from 75 to more than 1200. Overall claims reached

16 per cent of expenditures in 1984. Canadian-controlled firms claimed 52 per cent of the tax credits in 1984, a drop from 64 per cent in 1977.

Second, Canada's tax credits are quite generous by international standards, unlike the non-tax support.⁶ However, relatively few Canadian firms respond to these incentives. As Table 8 shows, actual Canadian tax support as a percentage of industry spending on R&D (8 per cent) is little higher than that of other leading industrial countries. Non-tax support, at 12 per cent, is far lower. Thus, through tax and non-tax measures, the United States supports R&D performed in industry with a 40 per cent subsidy, twice that of the Canadian subsidy. The main difference is in contracting out. Moreover, industrial R&D in the United States is three times as high a proportion of gross domestic product as it is in Canada. So the American government transfers nearly six times as much of national GDP into industrial R&D as Canada does. Hardly a level playing-field — certainly not in those industries in which competitiveness is premised on maintaining a technology lead or being a fast follower.

Table 8. Tax and Non-Tax Government Support for Industrial R&D as a Percentage of R&D Performed in Industry.

Country	Tax support	Non-tax support	Total support
United States	7	33	40
United Kingdom	8	29	37
France	7	22	29
West Germany	6	18	24
Canada	8	12	20

Source: Canadian Manufacturers' Association, *Improving Our Industrial Competitiveness* (Toronto, February 1986).

Third, there is now widespread acceptance, including by the prime minister himself, of the important role of industrial R&D both for continued leadership in knowledge-based industries and revitalized competitiveness of resource-based industries.

Assessment

To assess the potential impact of tax reform on industrial R&D, the Science Council commissioned a survey of leading R&D-performing firms.⁷ The survey addressed eight areas:

- Tax treatment of spending on buildings and structures;
- Investment tax credits (ITCs);
- Other corporate tax incentives;
- Corporate income-tax rate reduction;
- Phase 2 of tax reform;
- The effect of taxation on R&D output;
- Definition of R&D for tax purposes; and
- Other taxation issues.

The survey indicated that overall the tax proposals might deter industrial R&D. The news was not all bad — the reduction in corporate tax payments should confer a significant benefit, freeing working capital that could be used for industrial R&D, albeit also slightly raising the after-tax cost for R&D. However, the good news was countered by several pieces of bad news, at least as projected by the R&D performers. The nearly 50 diverse firms were anxious that the reforms not be essentially revenue-neutral. They identified the following likely impacts of the tax proposals:

- Lower cash flow and higher overhead, administrative and financial, would reduce funds available for R&D;
- Higher taxes payable as a result of changed treatment of R&D would be an increased cost for R&D;
- Investment in R&D facilities and the introduction of new products or processes would be delayed as costs were spread over longer periods. The proposed changes in capital-cost allowances would slow modernization and the application of best-practice technology;
- Competitiveness and the alternative of performing R&D in the United States would be key factors in corporate assessments of these tax reforms.

The primary concern was with the proposed 50 per cent cap on ITCs. That was seen as likely to seriously reduce levels of support for small, technology-intensive firms with large R&D efforts and limited tax liabilities. It was also viewed as leaving unsupported up to 40 per cent of the R&D performed by large technology-intensive firms in aerospace, electronics, and telecommunications, reducing their incentive to reinvest a high percentage of earnings in domestic R&D.

In effect, the tax reform proposals were perceived as not sending the right signals to those more technology-intensive firms that Canada most needs to nurture. Those who most need ITCs were the very ones likely to be unable to make full use of them. Yet the tax mechanism is Canada's chief chosen instrument to support R&D. The House of Commons Standing Committee on Finance, Trade and Economic Affairs argued that although the cap was intended to ensure that profitable large corporations pay some tax, it is more likely to remove support for the R&D of the medium-sized corporations that are the heavy performers of R&D.⁸

In light of these and other estimates of the impact of the government's proposals, the Science Council recommended they be reconsidered.

Follow-up

Following wide consultation on its tax-reform proposals, the federal government in early 1988 tabled a parliamentary motion to provide the legal framework of tax reform. Several points stand out. The government:

- In a conciliatory gesture, proposed a cap on R&D ITCs of 75 per cent rather than 50 per cent, which would produce a situation comparable to that in the United States, yet still indicate that the government is determined to collect tax from large profitable corporations;
- Stood firm on new write-off limitations and ITC restrictions for R&D buildings;
- Introduced a new restriction on the use of limited partnership financings for R&D, making the tax benefit the property of the R&D performer, not the third-party investor; and
- Stood firm on the reduction in the lifetime capital gains exemption from \$500 000 to \$100 000 and the increase in the rate of taxation on capital gains.

The product of these changes is some satisfaction at least with the changes to the maximum allowance for R&D ITCs, although the new provisions will still take an estimated \$30-50 million from industry. Some R&D managers remain distressed at the reduction in their ability to modernize R&D facilities at a time of accelerating obsolescence. There

are concerns in Quebec that restricting limited partnerships for financing R&D has seriously eroded the attractiveness of the large personal deductions that the province provides for investments in flow-through shares in R&D limited partnerships. There is also concern that participants in precompetitive R&D consortia will be unable to use ITCs or claim tax deductions unless the R&D is related to their business at the time the expenditure is made. The financial community is concerned that closing loopholes in the incentive mechanism will diminish the interest of those in high-income brackets in investing in R&D. The R&D community is worried that it will become much more difficult for small, technology-based businesses to claim ITCs for R&D expenditures. The venture-capital community is distressed that taxation of capital gains at a higher rate than dividend income will funnel investment funds into fixed-income instruments and high-yielding common shares.⁹

The government has chosen, by eliminating tax shelters, including partnership R&D financing, to give greater weight to fairness than to further enhancing competitiveness. In closing a major source of R&D financing and by making the tax system much more restrictive, the federal government has also seriously dampened the climate for innovative new companies. With the free trade deal in place, is fairness the most appropriate yardstick for evaluating this latest tax reform? To make the Canadian economy more efficient, flexible, and innovative, and the tax system fairer and more encouraging to the enterprising, will require further change to the tax system. Nevertheless, given the government's stated policy of phasing out many ITCs, the retention of them for R&D is, in a relative sense, positive.

Free trade agreement: a big leap in a nervous global economy

The second issue with the potential to have a major impact on Canadian industrial technology development and diffusion is the free trade agreement (FTA) negotiated in 1987 between Canada and the United States.

Background

The FTA has the potential to have a significant direct and indirect impact on the development and diffusion of Canadian industrial technology. Yet the Canadian debate has largely lacked a distinctive science and technology (S&T) element. The intent of this section is to analyse the

FTA's implications for industrial S&T from a Canadian perspective. Understanding these probable implications is important for those who consider improving Canada's technology base to be key to economic renewal and future prosperity. The section provides:

- A brief commentary on motives;
- An overall analytical and contextual viewpoint;
- An S&T perspective regarding tariffs and customs, government procurement, telecommunications, temporary entry, investment and technology transfer, competition and technology transfer, intellectual property, subsidies and dispute resolution; and
- A final commentary on where technology issues fit into the heart of all of the discussion on the FTA.

This section on the FTA was released as a manuscript report in September 1988, to contribute to the national debate. It does not address the impact of the FTA on the national standards system. (The FTA provides that technical regulations and standards not create unnecessary barriers to trade and both governments agree to harmonize their regulations to the greatest extent possible.)

Motives

Canada's main motive for this agreement was to avoid American protectionism, which in the mid-1980s threatened the 70 per cent of Canadian exports that go to the United States. The problem was how to preserve, let alone improve, Canadian access to the American market in the face of mounting American harassment and recourse to countervailing duties.

The second Canadian motive for free trade, long advocated by many economists, for whom free trade is close to a sacred tenet, was to improve productivity, reduce production costs, and enhance Canada's competitiveness, thereby raising income levels. Proponents argued that giving Canadian producers access to a much larger market would encourage greater specialization and lead to economies of scale. The latter is the premise for much of the benefit from liberalized trade and the reduction or elimination of disparities in productivity in the two countries.¹⁰

The validity of both motives looked less compelling by 1988. The depreciation of the American dollar against European and Japanese

currencies had significantly reduced the threat of American protectionism. President Reagan had vetoed the initial version of the 1988 protectionist omnibus trade bill, which had already been toned down to make it much less threatening. Surely the interests of the Americans, now the world's biggest international debtors, lie overwhelmingly in keeping other countries' markets open to their exports (which the massive realignment in currencies will only partly facilitate especially in the face of Japanese technological sophistication), rather than precipitating further wars of protection and retaliation? The diminished threat of American protectionism should alleviate Canada's disappointment at being unable, in the FTA negotiations, to get changes in American trade-remedy laws and to make advances on security of access.

Similarly, there is now greater doubt that the economies of scale to be derived from liberalized trade will lead to major advantages to Canada. This is the result of new technologies that emphasize scope and flexibility plus a greater understanding of the bases for international trade and the upper limits of scale economies.¹¹

General assessment

Now that the FTA has been ratified by both sides, what are the implications for S&T? The S&T issues tend to be difficult to disentangle from other elements. Consider first, however, some overall points:

- There is a legitimate concern that the FTA will diminish government access to the levers of power, this in a world of economic interdependence that already limits government action. Balance that, however, against enhanced corporate access to a much larger market and all the opportunities it entails. Is corporate Canada confident the new forces will work in Canada's national interest? Generally, yes. Will the gains of those who are capable and prepared outweigh the losses of those who are not, who will likely be swept aside by competition from American businesses that have the surplus capacity with which to swamp the Canadian market? The answer, particularly from those with confidence in the ability of Canadian companies to adapt, is probably yes. But who can tell, with such an amalgam of forces at work?
- Various simulations suggest scientists and engineers in advanced- and medium-technology firms — which is where most of those in

the industrial sector are employed — would face either small net job losses (particularly in electrical products) or minor net job gains. These changes would be dwarfed by the net gain in sectors such as construction and retail trade.¹²

- The projected net gains in jobs from the FTA — 120 000 by 1993 (Department of Finance), 150 000 by 1997 (Conference Board of Canada), and up to 250 000 by 1995 (Economic Council of Canada) — are modest in relation to the average 260 000 new jobs created annually over the past five years. Contrast that with the Department of Finance's estimate that even without the FTA the Canadian economy will produce about 285 000 new jobs annually. The FTA benefits are premised on significant adjustments by Canadian business in the face of intensified competition. Note, however, that the view has been expressed that benefits from the FTA may be offset by a jump in the federal deficit.¹³
- Estimates of job and productivity gains from free trade range widely; they are based on inherently static models with primitive data, and the variations are partly traceable to different assumptions about production technologies and pricing and demand parameters. The estimates inevitably fail to take account both of dynamic consequences (including those that are S&T-driven) and of intangible benefits and costs, many of which are important.¹⁴ The forces at work cannot be precisely weighed.
- The FTA will change the structure of the North American economy. One balanced assessment suggests, "It seems certain that the FTA will substantially increase the significance of national comparative advantage as between Canada and the United States. The Agreement, even without any provisions regarding subsidies, will also reduce the capacity of Canadian governments to counter continental market forces. This may be inevitable in any event. To the degree that investment is increasingly allocated to sectors of comparative advantage, Canada can expect a renewed emphasis on its resource-based industries...and perhaps a relative weakening of knowledge-intensive sectors involving tradeable goods and services.... Many would find this prospect extremely unsettling particularly when account is taken of likely breakthroughs in the creation of artificial materials."¹⁵
- Ultimately the real test of the FTA will be how well the business community responds to the new opportunities by exploring new

markets, forming new strategies, confronting new competition, and making large domestic investments. Many major Canadian corporations were already moving, in anticipation of the FTA's implementation, to rationalize and specialize, to compete on a continental basis. Some American-based and Canadian-based multinationals in the medium- and high-technology sectors have already moved far toward integrating their North American operations.¹⁶ Many large multinationals are in Canada because of country-specific advantages, especially access to oil, gas, forests, and mines, and the FTA will have little bearing on their investment decisions. The phasing out of the American tariff on processed minerals, however, could lead to increased R&D here.¹⁷ And access to the American market could strengthen the position of such large R&D performers as the provincial hydro companies.

- A significant appreciation of the Canadian dollar could affect the viability of American subsidiaries that operate in Canada with a relatively small competitive advantage based on cost. The risk for Canada is whether such multinationals will base decisions on their American interests rather than economic merit. There is evidence that foreign firms are not more inclined than Canadian ones to shift production from Canada to low-cost foreign sources, and may even be less footloose than domestic firms.¹⁸
- It is less the adjustment paths of the big players, especially those who now perform R&D, than those of the multitude of smaller firms that gives concern. The smaller firms, particularly those in import-competing sectors, may have less capacity to adjust to the FTA. And it is the small firms that have been by far the largest creators of jobs in recent years.
- The advanced-technology industries, as reflected by their trade associations (the Canadian Advanced Technology Association, the Aerospace Industries Association of Canada, the Information Technology Association of Canada, and the Canadian Chemical Producers Association), support the FTA with minor reservations. Small business, according to surveys by the Canadian Federation of Independent Business, has become increasingly supportive following release of the details of the final agreement; although nearly one-third are undecided, just over one-third think the FTA will be to their benefit.

- There are genuine fears among the advanced-technology community that, without a more generous tax and subsidy system to counter public support in other countries, the conditions of the FTA will mean less incentive for multinationals to increase R&D in Canada. Under these circumstances, the pull of the market south of the border plus easier access to risk capital there will likely entice Canadian-owned firms to shift R&D there.¹⁹
- The failure of the FTA negotiations to arrive at a mutually acceptable definition of a subsidy leaves undetermined the permissible scope of cooperation between the public and private sectors. How much government support of technological initiatives is legitimate is not clear. The point is crucial, as virtually all technology developed in Canada must, directly or indirectly, be exported to the United States for commercial success. A heightened concern for collective rights and the temptation to turn to government, at least for non-defence subsidies, have long been more prevalent in Canada than in the United States. Any pressures to turn over more decisions to the free market in the North American context will inevitably mean the free market forces will be American-driven.²⁰

A technology perspective

In May 1986 the Science Council of Canada stated that it was of paramount importance in the negotiations that technology concerns be placed up front to enhance domestic technological capability. The Council argued:

Canada cannot afford, by neglect if not intent, to opt out of the global technology race. Assured access to a larger market must be negotiated. To reap the rewards of investment in R&D and new technologies requires good access to large, if not global, markets. But market access alone is insufficient to enhance technology development. Technological competence is a principal driving force and vital key to future wealth; it cannot depend entirely on market forces. Nowhere is that better understood than in the United States.²¹

What did the negotiators achieve? From a technology perspective, they made some big steps forward in the traditional area of tariff reductions. But many technology issues proved complex to handle, and on some of these issues there was insufficient time to come to an agreement; broadly, little was gained or lost.

Tariffs and customs

The FTA provides for bilateral elimination by 1998 of tariffs in three stages. Most advanced-technology products will face no tariffs by 1989, the main exceptions being some chemicals, instruments, machinery, and large telephone-switching equipment. Both countries will continue to apply their present tariffs to imports from third countries. To be entitled to duty-free treatment, however, goods must comply with the rules-of-origin provisions. For instance, goods originating outside Canada or the United States must undergo substantial transformation through processing or assembly and thereby acquire Canadian or American content or added value. Chemicals, machinery, automobiles, and electronics, for instance, must have 50 per cent Canadian or American added value. The test to be applied is causing some concern to the advanced-technology community, in that it requires a complex calculation that threatens to be administratively expensive. Moreover, the rule will probably "provide a strong incentive, particularly for Canadian manufacturers, to source components in North America, even if these are not the most economical sources, in order to retain duty-free treatment at the Canada-U.S. border."²²

By value, about 75 per cent of the products now crossing the Canada-United States border do so free of duty. Elimination of the remaining tariffs should benefit both the many Canadian firms that are now paying tariffs on their essential inputs and those confronted by high American tariffs. Similarly, tariff harmonization and better access to the Canadian market will stimulate exports to Canada by small and medium-sized American firms previously reluctant to market outside the United States. However, probably the most important aspect of these tariff provisions is that they contribute an important incentive for firms from outside North America to set up business in Canada to serve North American markets.

Government procurement

The FTA made only small advances in government procurement, particularly in procurement of technology-based goods and services. The agreement lowers to U.S. \$25 000 (from U.S. \$171 000) the threshold at which government contracts are open to American and Canadian suppliers. The estimated value of the new opportunities is decidedly modest, however — less than 2 per cent of the present government

market in the United States. More importantly, however, FTA provisions allow greater access in the presolicitation, tendering, and bidding phases, require greater transparency for procurements above the threshold limit, and develop new principles for challenging bids. These features should stimulate procurement activity and provide new opportunities for suppliers.

The modest improvements in government procurement did not extend to the present Defence Production Sharing Agreement (DPSA). The DPSA ensures virtual free trade in most defence materials and equipment. An important exception is the American provision for government departments to set a small amount of their procurement aside for American small business. The provision is a major impediment to Canadian firms trying to sell in the American defence market, and the FTA did not deal with it. Seventy-five per cent of Canada's defence firms are classified as small business.

There remain important unanswered questions that have significant implications for domestic technology. One concerns the compatibility of the FTA with the Canadian government policy of "rationalization" status. That status enables a foreign-based company to be treated as a national company but subjects it to various requirements, such as performing R&D in Canada, conveying other industrial benefits, or undertaking offset obligations, when tendering to major government needs. As one senior executive has pointed out:

The policy of rationalization strongly influences where a company may establish its manufacturing operations, where a company may purchase its components, where it will undertake research and development, plus the manner and extent to which funds flow from the Canadian operations to the parent company.²³

Also requiring attention is whether the procedural requirements that go beyond those in the General Agreement on Tariffs and Trade (GATT) code apply to procurements above the FTA threshold of U.S. \$171 000.²⁴

Telecommunications

Telecommunications is Canada's leading advanced-technology industry and is by far the largest performer of industrial R&D. It is protected by relatively high tariffs and significant non-tariff barriers, notably the preferential-supplier agreement between Bell Canada and Northern Telecom. Under the FTA, Canada has agreed to open some of

its markets, particularly by relatively rapidly removing the tariff barriers. But the FTA has not addressed several non-tariff barriers, including the procurement practices of Canadian telephone companies.²⁵ However, the FTA does require that both countries move against predatory conduct and other abuses engaged in by telecommunications monopolies.

Temporary entry

Delays in — even denial of — temporary entry to conduct business are considerably irritating and burdensome to business people, especially those in Canadian advanced-technology firms. The FTA streamlines procedures and reduces the discretionary measures by which officials can arbitrarily hinder temporary entry for business persons. Thus, for those in specified occupations and professions, including research and design personnel and certain research assistants, both countries have agreed not to require prior approval, petitions, labour-certification tests, or similar procedures. Subject to certain qualifications, they have also agreed to similar commitments for traders, investors, and intracompany transferees.²⁶

Investment and technology transfer

The primary effect of the FTA on technology transfer will probably be felt through the provisions that protect investment and thereby should encourage it and hence increase technology transfer. The FTA represents a modest shift in Canadian investment policy. Both governments agreed that a "hospitable and secure investment climate is indispensable if (Canada and the United States) are to achieve the full benefits of reducing barriers to trade in goods and services."²⁷ The FTA in effect goes a little further toward the liberalization of capital movement taken in the 1985 Investment Canada Act. However, the FTA grandfathers all current discriminatory measures and maintains substantial discrimination in both countries' investment regimes. Among the provisions retained are qualified rights to tax or subsidize in a discriminatory way.

The FTA defines investment relatively narrowly. The definition deals with the establishment, acquisition, or operation of an existing or new business enterprise. It does not cover intellectual property rights or licences, permits, or other rights conferred by contract. The FTA

continues to permit direct acquisitions of companies, but changes the level at which no government permission need be sought in annual steps from Can. \$25 million in 1989 to Can. \$150 million in 1992. And it phases out reviews of indirect acquisitions by 1992. Phasing down the review mechanism may encourage investment and the associated transfer of technology but may not encourage the technological competence and distinctiveness on which to build a new sort of competitive advantage.

An important element of the FTA is the basic principle of “national treatment,” which is “a sovereignty-respecting principle. It makes no attempt to define national objectives; it merely regulates the means of achieving them.”²⁸ For a variety of specified measures national treatment requires each country to accord to investors from the other country treatment that is no less favourable than that accorded to its own investors in similar circumstances.

An irony of the FTA investment provisions is that, whereas they were of greater interest to the Americans than to the Canadians, the elimination of tariffs in practice removes one of the incentives for American investment in Canada. And there are problems in interpretation. For example, “although Canada is agreeing to limit investment-related performance requirements, it does not interpret the FTA as precluding the negotiation of product mandate, research and development, and technology transfer requirements with investors. U.S. companies may argue that these are equivalent to performance requirements.”²⁹ The interpretation is important. Canada is among the most assertive advocates of performance requirements, which have been consistently opposed by the United States.

One feature of the FTA that may be significant is a prohibition on any performance requirements for third-country investors that could affect trade between Canada and the United States. Transfers of foreign technology to Canada may be affected by this provision. For example, if Canada were to require a foreign company to do research and development in Canada in connection with its investment here, the company would not do that R&D as part of an investment it may also be making in the United States. The Americans might argue such requirements ultimately distort trade and should be prohibited.³⁰

Intellectual property

The FTA is largely silent on intellectual property, though it briefly acknowledges its importance to trade and investment. Instead it

provides for the two countries to cooperate in the Uruguay Round of multilateral trade negotiations and in other international forums to improve protection of intellectual property.

The Americans were interested in a separate chapter on intellectual property in the FTA, to address several long-standing irritants in trade between Canada and the United States. But this interest was outweighed by their reluctance to exempt Canada from American trade laws, notably section 337 of the United States Tariff Act of 1930. Section 337 has a much-criticized requirement that complaints of unfair practice in intellectual property must demonstrate injury. It has been used principally as a defence against patent infringement by imported goods. More recently it has become a major weapon against high-technology and other products that infringe not only American patents but also trademarks, copyright, and trade secrets.³¹

Competition and technology transfer

The FTA makes no specific reference to competition or anti-trust laws. But essentially it does complement Canada's 1986 Competition Act, which itself is largely compatible with American competition law.³² The FTA will affect the application of each country's competition laws insofar as the two countries will be viewed as largely one economic market unit.³³ That will influence the evaluation of a proposed merger or joint venture and reduce the likelihood of interference on anti-trust grounds when firms decide to expand, make specialization agreements, merge, or make acquisitions to become more internationally competitive.³⁴

In one respect the FTA may indirectly alter the application of American anti-trust statutes. A supplier or manufacturer will still be able to limit a licence granted under the American or Canadian patent to exclude sales to one or the other country. Not so, however, if the technology being licensed is unpatented. There is some concern that the FTA may change the rules sufficiently to make restrictions designed to separate American and Canadian markets more susceptible to anti-trust attack.³⁵

Subsidies and dispute resolution

A major concern for the Science Council of Canada and members of the S&T community, especially in view of the technological asymmetry

between Canada and the United States, was that the FTA should include a clear, mutually acceptable definition of allowable, non-countervailable, government support of R&D and innovation. In the event, the negotiators differed over the role of government in business and society. They could not agree on a definition, and neither side was willing either to give up its own subsidies or to exempt the other's subsidies from the application of unfair trade remedies. The R&D and innovation subsidies were reputedly less contentious, however, than subsidies in other areas.

The FTA does not include a subsidies code. But it does make provision to negotiate over five years common rules and disciplines concerning government subsidies and unfair pricing. The provisions for resolving disputes in the FTA include joint panels to determine whether countervailing-duty legislation violates the FTA or GATT. This is a significant restraint on promoting new, protectionist measures under the guise of countervailing duty.³⁶ A key contribution is the FTA's special provisions on dumping and countervailing duty, which incorporate shorter and more certain time limits.³⁷ They should be of particular advantage to smaller firms. Also,

The bilateral character of the panels will encourage a better balance between Canadian and U.S. views on the applicable law, and above all a greater perception of fairness and objectivity. The cost of appeals will no longer frustrate the rights of small businesses, since they will be entitled to have their views presented by their government before a binational review panel.³⁸

More important than the improved mechanisms for settling disputes are the FTA rules to bring predictability and stability to private and public international relations, and the commission that will supervise the implementation of the FTA.³⁹

Heart of the debate

At the heart of the FTA debate in Canada is not the number of jobs affected or created and where they are likely to be, or the amount of increased wealth, but the very different conceptions of the nature of Canada, the role of market forces in Canada, and the potential to sustain a truly sovereign Canada. The technology issue is a small, albeit significant, part of the debate, involving the ability of future Canadian governments to manipulate the necessary tools to move the country in desired directions. The issues in the debate are profound, complex, and

surrounded by uncertainty about the intensity and impact of the many forces at work. Truly, acceptance or rejection of the FTA can only be "a leap of faith" in a nervous and profoundly changing global economy.

Nervousness is hardly surprising in the face of enormous global trade imbalances and huge American budget deficits, neither of which are diminishing fast enough for comfort or confidence. Since 1982, the United States has been transformed from the world's largest creditor, with net foreign assets exceeding \$400 billion, to the world's largest debtor, with a net external debt of close to \$500 billion. The condition of Third-World debtor countries, unable now to service their debts, let alone reduce them and at the same time grow, has also deteriorated further during a decade in which there has been an increasing reverse flow of capital, from the poor countries to the rich. The United States has become a major sump, sucking in capital from abroad to finance its own massive public and private debts.⁴⁰

Is the day of reckoning at hand for the United States? Surely it must face wrenching adjustments over the next decade. Was it wise for Canada to bind itself even closer to the United States and further limit the powers of its government to intervene? Does the FTA cede too much decision-making? Or is the new global order that is now emerging such that there was little choice, and much sovereignty will need to be ceded anyway?

In the meantime, it would be more than a pity should Canada's preoccupation with the FTA be allowed to distract us from:

- The enormous potential benefit to be gained from directing our S&T and economic policies toward stronger ties with Japan, with its awesome new wealth; and
- The need to come to grips with the major problems and opportunities that will arise when, as proposed for 1992, the European Community phases out all internal barriers to trade and introduces other sweeping reforms.

S&T and regional development

In Canada, as in other advanced countries, it is evident that the approaches to regional development, based on modest expenditures, that have been tried over the past two decades have not been effective.⁴¹ The approaches were largely based on the idea that the federal government had a responsibility to redistribute income through transfer

payments and to improve regional capacity to generate wealth and employment by attracting new industry and modernizing existing industry. This was to be achieved mainly through grants and tax incentives for development and the provision of infrastructure. In practice, federal transfers to compensate for underdevelopment have heavily overshadowed development expenditures. Over the past five years, however, it has become obvious that this conception has failed to generate sustainable economic activity.

Canadian regional inequalities, though not large by many standards, remain the basis of intense grievances.⁴² The causes of the inequalities are still subject to much dispute; the arguments are philosophically confused, theoretically unsound, and empirically undemonstrated.⁴³ That makes it difficult to propose appropriate policies, a problem reinforced by confusion about the goals of federal regional policy and their consistency with provincial preferences and the fact that process is important in policy-making in a federal state.⁴⁴ The situation becomes muddier in that it is considered important to accommodate provincial preferences, to reconcile the parts and the whole. And those preferences are unlikely to be simultaneously satisfiable. In this fuzzy realm, S&T issues are becoming increasingly pertinent, as both problem and solution.

In the crafting of S&T strategy, geography matters.⁴⁵ Policy-making is closely associated with Canada's enduring tensions: federal-provincial, English-French and Canada-United States. National technology policies cannot simply be injected with a regional dimension, and regional policy needs to be considered in the context of national technology, economic, and other policies.

Regional development efforts must take into account that:⁴⁶

- Technical know-how and competence are becoming more important as factors of production and in the location of industry;
- Self-generating regional growth requires a high rate of innovation and entrepreneurship to start up new firms;
- Entrepreneurship is more vigorous where such features as venture capitalism, information infrastructures, including education and training systems, and technology centres are well developed and where small business is active;
- Regional competitiveness is largely a function of the mix of industries and technological capability; particularly important is the

ability of indigenous engineering firms to apply best-practice technology;

- Better access to information and highly skilled labour tends to make industrial renewal more likely in urban areas.

The information technologies can sometimes help offset the problems of geographic concentration and market access. Distance from markets, for instance, is less important for computer-software and data-processing firms that have good telecommunications.⁴⁷

In regional policy, emphasis on technology transfer and diffusion has become more important in recent years in offsetting the advantages of the cities and the tendencies of information technologies toward geographic concentration.⁴⁸ Regional development has focused increasingly on higher-education institutions in generating spin-off firms, enhancing the regional diffusion of technology — especially to small and medium-sized enterprises — forming research links with local firms, and supporting cooperative education. A shift is occurring from measures that defend past investment to ones that promote new technology and training.

Pivotal elements and issues

Four pivotal elements dominate modern thinking on regional policy in Canada, as elsewhere:

- Decentralization, with the federal or central government involved as just one of the participants in planning and implementation;
- Stimulation of local capability, focusing particularly on entrepreneurship and vibrant small and medium-sized enterprises to create new jobs and assist diversification;
- Provision of S&T infrastructure and promotion of the development and diffusion of technology as key tools; and
- Increasing focus on regional competition and specialization, with a premium on flexibility and adaptability. The growing service sectors and knowledge-based industries are attracted to, and stimulated by, dynamic urban centres with a well-endowed information-technology infrastructure.

Small, young, advanced-technology firms in particular flourish in large, diversified urban economies. There they are more likely to have

the advantage of access to highly specialized production inputs as well as the professional and technical service expertise that is too expensive to maintain in-house. They can draw on producer services in product design, development and testing, marketing, and management consulting, and the better air service provides prompt access to suppliers and for customers.

The new prominence for S&T in regional development inevitably raises an amalgam of S&T policy issues and leads to vigorous struggles for funding between regional industries and intense intraprovincial and interprovincial rivalry, especially for federal S&T-related expenditures. The maintenance contract for the CF-18 fighter and the location of the new space agency are vivid examples.

What S&T infrastructure is appropriate for regional development? Should it be city-oriented to attain critical mass? Should the investment emphasis be on infrastructure, education, and training highly qualified personnel, on strategic technologies, or perhaps on improving the acquisition and adoption of technologies? Is it better to build on existing strengths — say, S&T to strengthen the dominant forest sector in British Columbia — or to diversify into areas with new potential, as Alberta and Saskatchewan are attempting to do? How much should be spent or could effectively be used? Should federal S&T expenditures across the country be allocated equitably or flow to where the potentials are greatest? Do programs that rely on private-sector response to government initiatives unduly disadvantage regions that now lack industry? Will market forces further increase the regional disparities that derive from regional differences in technological endowment? Will building on strengths only exacerbate regional disparities? Are appropriate networking and cooperation taking place at the local level by local, provincial, and federal actors, especially in metropolitan areas? What level of collaboration and harmonization is required or might reasonably be expected, especially between participating governments? Are the evolving roles and responsibilities of governments in S&T suitably mapped and accepted, and who should fund and who should perform the R&D or provide the technology diffusion services?

The issues are complex and interwoven. There is a need for better understanding of the role of R&D and technology in regional development, to help develop appropriate principles to guide action. Each of the following five sections considers a key issue with regard to regional development and the diffusion of industrial technology.

Regional R&D capabilities, private and public, are increasingly seen to be one of the more important components of the infrastructure contributing to regional development.⁴⁹ There are wide differences between regions. One indicator of capabilities is the proportion of gross domestic product represented by gross expenditure on research and development (GERD/GDP). The national average in 1984 was 1.25 per cent. Only Ontario (1.72 per cent) and Nova Scotia (1.46 per cent) exceeded the national average. Five provinces stood below two-thirds of the national average: New Brunswick (0.63 per cent), Saskatchewan (0.69 per cent), Prince Edward Island and British Columbia (0.73 per cent each), and Alberta (0.8 per cent). Some distinctive features of the distribution of R&D performed in Canada are (Table 9):

- The strong performance of business enterprise as both funder and performer of R&D in Ontario. Ontario did \$2.3 billion of the \$3.8 billion of R&D performed by business enterprise in Canada in 1986;
- The predominance in the Atlantic provinces of funding and performing of R&D by the federal government rather than business enterprise;
- The role of provincial government funding in Quebec, which at \$152 million exceeded the \$140 million spent by the Ontario government. The federal government performed one-fourth as much research in Quebec as it did in Ontario, and the private sector just over one-third as much. However, a major portion of federal expenditures in Ontario are in the national capital region (Table 10);
- In the western provinces, the private sector performed more R&D than the federal government, except in Manitoba. Alberta is unusual for the high level of provincial funding of R&D;
- All told, the federal government funded about five times the R&D funded by provincial governments. It is the main contributor to reducing regional disparities in R&D spending.

Industrial R&D tends to be very highly concentrated in Canada, as it is in the United States.⁵⁰ Just three metropolitan areas, Toronto, Montreal, and Ottawa, for instance, between them account for more than 60 per cent of Canada's total industrial R&D.

Table 9. Regional Distribution of R&D, 1984 (\$ 000 000).

Province	Performer			Funder		
	Federal government	Provincial government ^a	Business enterprise	Federal government	Provincial government ^a	Business enterprise
Newfoundland	25		4	37		4
Prince Edward Island	9		11	14	1	4
Nova Scotia	87	4	27	124	3	14
New Brunswick	25	6	25	51	5	10
Quebec	175	59	872	437	152	632
Ontario	789	66	2311	1203	140	1837
Manitoba	86	5	30	113	9	24
Saskatchewan	41	9	54	65	21	42
Alberta	75	49	238	131	109	182
British Columbia	104	17	254	208	26	173
Canada ^b	1417	215	3828	2384	466	2924

^a Includes provincial research organizations.

^b Includes Yukon and Northwest Territories.

Source: Statistics Canada, Science, Technology and Capital Stock Division, *Estimates of Canadian Research and Development Expenditures by Region, 1979 to 1986 (revised)* (September 1988).

Table 10. Federal S&T Expenditures by Region as a Percentage of Total S&T.

Region	1981-82	1982-83	1983-84	1984-85	1985-86
Yukon and Northwest Territories	0.1	0.1	0.1	0.1	0.8
British Columbia	8.1	9.2	9.2	8.7	9.5
Alberta	6.3	5.0	5.1	5.6	5.7
Saskatchewan	2.5	2.5	2.7	2.6	2.8
Manitoba	5.8	5.8	6.0	5.9	4.7
Ontario (excludes National Capital Region)	22.9	22.2	21.5	21.7	22.3
National Capital Region	31.5	31.2	29.7	28.8	25.1
Quebec (excludes National Capital Region)	13.4	14.1	14.7	16.6	18.6
Atlantic provinces	9.4	9.9	11.0	10.0	10.5
Canada	100.0	100.0	100.0	100.0	100.0

Source: Statistics Canada, *Science Statistics*, cat. no. 88-001, 12, 7 (July 1988): 3.

There are important distinctions, of course, between Canada's three major advanced-technology communities.⁵¹ Toronto is characterized by its great size, diversity and synergy, relative emphasis on electronics and telecommunications, and predominance of large foreign-owned subsidiaries; Montreal by its focus on aerospace and pharmaceutical industries, dominance by five large firms and greater dependence on public (including foreign government) expenditures, and the smaller Ottawa complex by its focus on telecommunications and electronics, the predominance of Canadian ownership and small firms, and the towering presence of the Bell-Northern Research labs.

Any effort to reduce such concentration in central Canada would run against strong economic forces. The experience of many advanced industrial countries is that R&D-based technological innovation is a markedly metropolitan phenomenon. The main advantage of performing industrial R&D in big cities is the better access to information, venture capital, producer services, skilled labour, and universities. As in the United States, the tendency in Canada is the larger the city the greater the concentration of industrial R&D; research outside big cities tends to be performed in small universities or government labs. Regional development policies must therefore be framed with regard to the good reasons there are for concentrating industrial R&D. A policy that aims to accommodate regional demands for R&D facilities may face

a difficult trade-off with efficiency. The problem in a federal system is: can S&T resources be concentrated, by location and by sector, without exacerbating regional disparities?

Ontario and Quebec initiatives

The jockeying for position by the provinces, who are aggressively filling a perceived gap in federal leadership, creates tension. Most provinces, unlike states in the United States, are focusing on specific industries and on processes — technological innovation, capital formation, new business formation, the commercialization of research, and the adoption of new manufacturing technologies.⁵²

Events from late 1986 to early 1988 demonstrate federal-provincial and interprovincial interplay. Consider recent major initiatives by Ontario and Quebec to expand their R&D capabilities, and the impact these may have elsewhere in the country. In late 1986 Ontario announced a 10-year, \$1.1 billion technology fund, half of it new money, to stimulate strategic joint ventures in R&D and technology application and thereby enhance the long-term competitiveness of Ontario industry. First came the \$200 million over five years for seven “centres of excellence.” The centres are intended to have close industry partners and are designed to build on existing strengths. Generally they involve networking between several universities and are themselves university-based. The initiative has stimulated considerable enthusiasm within the Ontario S&T community. It is widely seen to be far superior to the federal government’s matching-funds scheme. Already, despite formidable implementation problems, it has an aura of success. This raises well-based fears that it could depopulate laboratories elsewhere in Canada unless the scheme is adopted nationally, as the federal government in 1988 was rightly attempting to do. National implementation has the inevitable problem of how to support excellence in the face of excessive politicization and regional pull.

The Quebec government, partly to counter Ontario’s aggressive efforts, chose a different path. In its April 1987 budget the provincial government added to its wide range of measures to attract S&T investment and boost the province’s R&D capabilities by introducing innovative tax measures and grants that could pump an estimated \$142 million yearly into business R&D and university research. The budget also provided strong inducements for university-industry links. The measures are designed, among other things, to help attract world-class

foreign researchers to join Quebec companies or universities and colleges, and to offer the most favourable fiscal environment for R&D in Canada. A major part of the tax package, originally expected to cost \$46 million per year, is a 33 per cent rise in the allowable personal deductions for industrial R&D flow-through shares. The impact of this measure has subsequently been severely reduced by the 1988 federal tax reform measures, so pressure has been raised within Quebec for stronger direct R&D assistance.

Early in 1988 Ontario rejoined the fray, improving its R&D climate with budget measures that included:

- A 25 per cent increase in R&D write-offs for large firms but a 35 per cent increase for small ones;
- A five-year, \$38 million technology personnel program, subsidizing salaries of new R&D or technical staff;
- A 50 per cent tax deduction for incremental R&D spending; and
- A five-year, \$25 million strategic procurement program.

These measures should spur expansion in industrial R&D performance, particularly by new performers whose entire R&D effort would qualify as incremental spending. They also sweeten the Ontario R&D climate in relation to that of other provinces. And they provide a base against which Quebec and perhaps other provinces will raise the stakes.

Local initiatives

Metropolitan and local authorities are assuming an increased role in hustling for new jobs, linking universities, colleges, and business, and more generally contributing to regional development by S&T-oriented initiatives and interventions of one sort or another. In 1984 the Science Council recommended such a role.⁵³ Two-thirds of Canada's scientists and engineers reside in metropolitan areas; it is there, ultimately, that we need to ensure we have our act together, that the parts fit. Edmonton with its new city-sponsored Council for Advanced Technology provides one role model. And Montreal is a prime example of a community that has recently grasped the nettle and made strong efforts. It has drawn its key federal, provincial, and municipal actors together to assess strengths and weaknesses in using S&T as an engine of economic growth, to establish a communal sense of S&T investment priorities, and to

generate the political will and economic commitment to press for results.⁵⁴

Increased activity by lower-tier governments has many advantages when well directed, and when the objectives and demands for public-sector investment are studiously harmonized with those of other governments. However, it also raises the danger of escalating unproductive interurban, interregional, and intergovernmental competition, diminishing the capacity of higher-level governments to reduce regional disparities and further balkanizing the provincial and national territory. The need (and this may be wishful thinking) is for governments to coordinate their analyses and intentions, cooperate on objectives, methods, and financing, and harmonize their policies, through long-term arrangements where advisable.

Decentralizing decision-making

There are growing signs of interprovincial collaboration, at least among the Western provinces and provincial research organizations.⁵⁵ And there has recently been a trend toward allocating federal S&T funds on priorities mutually identified by the federal and each provincial government. The mechanism for this is the S&T-related subagreement under the federal-provincial Economic and Regional Development Agreements (ERDAs). Thus the subagreement with Quebec provides for \$100 million over five years (1985-90), to be split evenly between the two governments, on programs that include a national optics institute, an electrochemistry and electrotechnologies research laboratory, and various programs to support technology development. Four other provinces, so far, have signed S&T subagreements.

Recently, also, Ottawa's regional development programs have been decentralized and more explicitly focused on S&T. In 1987 the federal government formed two new agencies, the Atlantic Canada Opportunities Agency and the Western Diversification Office, and launched a new five-year program for the economic development of Northern Ontario, with its main office based in the area and drawing on a local advisory board. A similar program is expected for Eastern Quebec.

The largely reactive mandate of this decentralization is to give Canada's regions a more direct role in shaping the programs that affect them, to rely more upon local initiative and local ideas about what is best for the region, and to promote greater self-reliance. However, the funds

allocated in 1988-89 to these new programs hardly suggest a major program of economic renewal; details on their operation are only slowly emerging. Nevertheless, indications are that the programs will encourage a business-support system for research, S&T infrastructure, the use of technology to improve the competitiveness of small and medium-sized enterprises, the commercialization of leading-edge technologies, and diversification into knowledge-based industries.

One aspect of these regional agencies is of particular importance. They make it possible for new S&T initiatives to be directed as part of Canada's regional policy, and they can capitalize on the gains and new opportunities arising from the FTA. However, the FTA, which itself can be seen as a significant regional development initiative, should not constrain the goals of Canadian regional policy, although it could constrain some means by which those goals are served — especially by triggering countervail where subsidies or other incentives are export-oriented. The FTA could further highlight the role of S&T and other initiatives that feature human capital in regional policy.

Science parks and incubators

There is widespread preoccupation with the type of technology-oriented industrial complex that has seen some success in the United States. Many communities have created science parks or incubator malls and innovation centres, a largely real-estate element of the infrastructure.⁵⁶ Substantial advantages seem to arise when several technology-oriented industries are located close to each other. But such concentrations often take decades to develop. They are usually associated with large, privately or publicly owned R&D laboratories and the tendency, predominantly by the former, to spin off technology-based firms.

Such centres evolve in many ways, with different types of support by various levels of government and the private sector.⁵⁷ The experience indicates that new advanced-technology firms germinate best where:

- Skilled people in big firms are footloose and ready to leave;
- People who know how to get businesses going and enjoy doing it can be drafted to help;
- Universities are brimming over not only with ideas, but also with academics who want to make them commercial;
- Well-known entrepreneurs have already shown there are fortunes to be made and have spurred others into imitating them; and

- Investors are ready to take risks with their own or their clients' money.

The link of R&D to successful regional development is elusive. It generally requires a good mix of this complex amalgam of local ingredients.⁵⁸ The ingredients are only one necessary part of the recipe; in themselves they are not enough. Much, in addition, depends on the economic and political context, including the state of the national industrial and skill base. An understanding of this should help to prevent the undue expectations that can arise from overblown ideas of the role of technology, research, or science parks located beside universities to stimulate hi-tech communities. British science parks, for instance, have not been a resounding success, and most firms in them have only tenuous links with a university. The Cambridge Technology Park, probably the most successful of them, was more a beneficiary of the local growth of high technology than a contributor to it.

Similarly, few American university-affiliated science parks have thrived. Occupancy rates tend to be highest in communities where hi-tech has caught on for other reasons. The more successful parks are in or near a major urban region and are affiliated with a world-class research university. Indications are that communities should emphasize building the competitive research base before turning to real-estate solutions.

Whether such parks can prove useful depends on a variety of conditions — the diversity of university-industry links, local urban and industrial conditions, whether the culture of the university is sympathetic, the research strengths of the university, and other local influences — that are rarely to be found outside large metropolitan areas.

Incubator malls also can be useful.⁵⁹ They usually provide four types of resources designed to help “hatch” new businesses: facilities, secretarial support, administrative assistance, and business expertise. They are intended to support local entrepreneurs by reducing their problems of undercapitalization and managerial inexperience, raising their level of business planning, and providing a focus for government and community assistance. Yet even doubling the number of incubators currently functioning would be unlikely to influence the fate of even 1 per cent of the small businesses started up in Canada each year. It is not that there are no positive experiences — some incubators have indeed helped the growth of some of their tenants — but incubators are not an

important part of the broad entrepreneurial explosion sweeping the country.

It is not likely that the provision of publicly funded incubators in regions untouched by that explosion will help to produce new entrepreneurs. It is even less likely that an incubator mall, fostering private enterprises undertaking commercial R&D, would be cost-effective in regions without at least some larger advanced-technology firms and other services.

Geography matters

Information technologies have brought considerable changes in the nature of production and consumption. At the same time they diminish the constraints of time and space. Information grids make it feasible to disperse productive and organizational structures and increase functional and spatial flexibility, while maintaining coordination and control.⁶⁰ Yet key information-based activities continue to concentrate in cities, reinforcing the complex hierarchy of urban systems and the separation between conception and execution in the information economy.⁶¹ The technologies' potential for new mobility runs headlong into the inertia of the built environment and the weight of historical infrastructures. And centripetal forces continue to be refreshed. In the 1950s and 1960s they were led by demand-side urbanization, promoted by a Keynesian state emphasizing demand-led growth and building of infrastructures. That gave way in the later 1970s and the 1980s to a supply-side urbanization, less concerned with equity and social justice than with a thrust toward efficiency, entrepreneurship, and innovation, enhanced by joint public-private initiatives.⁶² What can now crucially balance the centripetal and centrifugal tendencies is information-communications policy;⁶³ however, the formation of such policy is hindered by the fragmentation of telecommunications regulation, making it difficult to establish national directions and priorities for investment. Effective policies are crucial when the availability of telecommunications-based network services is increasingly important for industrial competitiveness.

Geography does matter in the formation of regional S&T initiatives and strategies, and there are no simple quick fixes for linking industrial R&D and regional development. In fostering development through S&T, regions must focus on what they control and must depend on a strong public-private partnership for collaborative decision-making.

Chapter 6

Some Minor Issues: Irritants and Opportunities

Several issues of less importance than those in the previous chapter affect the development of industrial technology. Each was discussed during consultations in 1987 for the preparation of this report. They range from the space program to changes to the Patent Act and R&D tax guidelines.

Space program

In the past 25 years, Canada has successfully developed a small, innovative space industry, 90 per cent Canadian-owned and exporting more than 70 per cent of its products and services. The Canadian industry is unusual in that it is the first national space industry in the world with sales higher than its own government's expenditures on space.

The federal government's comprehensive space plan, announced in May 1986, is an important part of the government's R&D planning. It is designed to build on the prestige earned internationally by the technology developed for space and to diffuse and adapt it for more traditional uses.

So far the plan has evolved within the government's policy of fiscal restraint. It has three main components.¹ First is the design, development, manufacture, and operation of the Mobile Servicing System (MSS) for the American space station to which the federal government has now committed \$1.2 billion. Building in part on Canadarm technology, the project will drive a great deal of R&D in advanced robotics. Revenues from the MSS, plus Canada's own use of the space station, are estimated at more than \$5 billion, along with 80 000 person years of employment. The government hopes that the technology developed will be readily diffused and adapted by Canadian resource, manufacturing, and service industries, and that it will stimulate new, knowledge-based enterprises.

The federal government also wants the benefits of the program to be widespread across Canada. It has required the prime contractor for the system to help develop smaller suppliers outside central Canada —

in effect to train them for entry into the big-league space market. One challenge is how best to develop subcontractors, particularly to involve innovative small businesses as partners at earlier stages in proposals.

Second is MSAT, the Mobile Satellite, to be owned and operated by Telesat Canada for two-way radio and telephone communications across Canada. Though it has considerable economic potential, the program will not proceed for certain until close coordination with an American system is arranged and frequencies in the radio spectrum are allocated.

Third is Radarsat, a Canadian-led, international, collaborative project based on a Canadian satellite equipped with a new Synthetic Aperture Radar (SAR) system. If partners can be found to jointly fund this increasingly scaled-down project, it will extend Canada's acknowledged world leadership in remote sensing. The project will support further R&D by the prime contractor and a small number of principal subcontractors. The satellite's most valuable applications will be in monitoring and mapping renewable resources and aiding interpretation of complex geology.

Those who gave evidence in 1987 before the House of Commons Standing Committee on Research, Science and Technology regarding the MSS program were excited about its potential as a driver of technology and a beacon for Canada's best intellectual talents. The evidence included controversy about possible military uses, concern over the possibility that costs would balloon, and the fear that estimates of spin-off and job benefits may be greatly overstated. In fact, costs did start to rise sharply in 1988, raising fears that support for the project might impoverish other less glamorous ventures.

Canada's participation in the American space station project and Radarsat offers major opportunities for technology development. Whether the new space plan will do much to increase industrial R&D depends on these factors:

- Will there be additional resources for the programs, rather than reallocations from other government S&T expenditures?
- How much of the work will be contracted out to the private sector?
- In the long-term goal-setting, design, and implementation of the plan, will there be continuity in funding to forestall the break-up and irreparable loss of private-sector R&D teams?
- Can the supply of space scientists and researchers be raised?

Whether the development of the technology will generate wealth in Canada depends on whether enough attention is paid to doing so.

Key problems that continue to plague Canada's space activities are its fragmentation between federal agencies, instability of budgets, and the inability so far to arrange international cooperation and partnership agreements. The long and intense deliberations over where to locate the space agency reflected the difficult federal problem of how to resolve the competition between two cities and two provinces.

Bill C-22

Through the highly controversial Bill C-22, Parliament has changed the Patent Act to give stronger patent protection to pharmaceutical firms in return for commitments by industry representatives for increased R&D.² The government's objectives were to transform the industry into a dynamic, world-class, innovative industry by greatly increasing the amount of R&D conducted in Canada, to prevent a consequent abuse of prices, and to ensure that a chemical-manufacturing industry develops in Canada, generating employment and exports. The industry has agreed to raise R&D from the current less-than-5 per cent of sales to 8 per cent in 1990 and 10 per cent by 1996. That is expected to add about 3000 R&D jobs by 1996, in addition to which many other production jobs in fine chemicals may be created. The industry has also indicated that it intends to make greater use of universities across the country, thereby providing regional benefits in training scientists and ensuring more jobs for university graduates.

The government considers that Bill C-22 balances the needs of brand-name and generic companies, providing a reasonable period of exclusivity but maintaining the compulsory licensing system. The bill brings the Canadian patent system closer to the standard, among developed countries, provided for the protection of intellectual property, but maintains the distinctly Canadian usage of compulsory licensing.

The bill has four policy aspects — the treatment of intellectual property, relations between Canada and the United States, social policy on drug prices, and industrial policy. In February 1987 the Science Council endorsed in general the intellectual property provisions of the bill but raised serious concerns about its social and industrial aspects.³

The first of these concerns is the lack of attention to the creation of a large Canadian flag carrier to enter world pharmaceutical markets; this

remains especially debilitating in view of the enormous commercial potential of the heavily supported medical research in Canada. The second is that the industry has no legal obligation to honour its commitments. The third is the lack of definition of genuine research as opposed to clinical trials or minor, incremental changes to existing drugs. The fourth is the need to ensure that the research has a substantial impact on employment and the balance of payments.

The new law has big teeth in that, after four years, a parliamentary committee will determine whether the industry is living up to its commitments. The committee has the power to withdraw new patent concessions. In the meantime, the federal government will provide the provinces with \$25 million each year for R&D relating to medicine. This is compensation for any increase in drug costs resulting from Bill C-22.

R&D guidelines, Revenue Canada

In the fall of 1986, Revenue Canada released new guidelines on the tax treatment of spending on R&D. The guidelines, long-awaited, were designed to clarify not the definition of what constitutes scientific research and experimental development, but Revenue Canada's interpretation of the definition. The guidelines raised considerable concern as to how they would be applied to existing R&D incentive programs and how they would affect the level of industrial R&D. Revenue Canada personnel also were concerned about the difficulty of administering these R&D incentive programs equitably and cost-effectively, as well as identifying activities eligible to receive the R&D tax incentives. The essential tests for an activity to be eligible involve the three criteria of scientific or technological advancement, uncertainty, and content. A prime source of difficulty was the criterion of scientific and technological uncertainty.

Also in the fall of 1986 Revenue Canada clarified the term technological uncertainty, stating that it could occur in either of two ways:

- It may be uncertain whether the goals can be achieved at all; or
- The taxpayer may be fairly confident that the goals can be achieved, but may be uncertain which of several alternatives will either work at all or be feasible to meet the desired specifications, cost targets, or both.

Revenue Canada has since started to consult with the private sector over the key issues involved⁴—how to distinguish eligible experimental development from more routine activities that cannot qualify, the documentation necessary to demonstrate that a program is cost-effective, the treatment of research that complies with regulatory and certification standards, the clarification of terms (such as customary product design and routine engineering), and consistent interpretations on eligibility as R&D.

In September 1987 Revenue Canada further clarified its interpretations of these guidelines. The department is continuing dialogue with sectoral associations on the application of the guidelines, treatment of R&D expenditures (including claims on overhead and administrative costs), and issuance of advance rulings on eligibility.

Reactions by R&D-performing firms to the new interpretations are mixed. Some envisage positive effects, arising from the potential eligibility, for instance, of process optimization or the development of software for internal company use. But many firms among the 47 responding to a survey undertaken for this report express concern that the interpretations are not in fact broader but more restrictive and harder to comply with.⁵ The definition of eligibility may be broader, but it is seen to be offset by the tighter interpretation of projects qualifying for R&D by tax auditors. Added to that are the increased costs of providing the tax auditors with the documents they demand.

The survey shows that the new tax interpretations pose a dilemma to R&D management in costing and selling new projects. Emphasis on “technological uncertainty” helps satisfy Revenue Canada’s requirements but is likely to be unacceptable to the marketing manager. Yet emphasis on “certainty” helps leap the marketing hurdle only to confront more-likely rejection by Revenue Canada. The probable result is a dual standard, a detrimental effect and an added measure of confusion for corporate personnel.

Over the past year Revenue Canada has also raised its complement of scientists and engineers for technical assessments and has speeded up the processing of R&D claims. Delays in paying claims have created cash-flow problems that are particularly tough for small firms. In April 1988 the government improved this situation by cutting some of the red tape facing claimants and by expediting refunds. The department will issue the credits first, then scrutinize the claims.

Revenue Canada worked closely with the private sector to clarify how the guidelines should work in specific industries. A key paper released in the fall of 1988 covers software, the subject of a majority of claims for refunds and one of the most difficult for assessment. Disentangling the uncertainties in this area, developing tests of eligibility for activities and projects, and incorporating software industry terminology should help further the growth of industrial R&D.

Copyright of software

The federal government in 1987 introduced long-overdue legislation (Bill C-60) on the copyright of software. The legislation, passed in 1988, is crucial to the development of information technology. It provides software developers with an increased legal and moral right to the integrity of their work and should encourage more computer software firms to develop products in Canada.⁶ The principle behind the bill is to extend copyright protection to products such as software, which were not even thought of when the previous law was enacted in 1924.

The software industry has pressed strongly for the new law, which adds further ammunition to a recent legal conviction for copyright infringement. Some estimates are that software piracy has been costing the country as much as \$400 million a year. One expected advantage of the bill is that it should make the industry's large exports more secure, given the reciprocity in international copyright conventions. It may also aid the entry and survival of small firms, though many still are not conversant with the law and probably lack the resources to protect their software in the courts. That their work will be more protected by an enforceable act should provide some confidence for software developers, but some large firms remain sceptical.

Regulatory practices

Successfully managing the national innovation system requires a climate to support a mix of small and large companies. The issue is whether our public- and private-sector practices too often favour bigness; do our regulatory practices inadvertently discriminate against the emergence or survival of small companies? An example is the seemingly inordinate time taken to make bureaucratic decisions, particularly to establish an acceptable regulatory environment for commercialization of

biotechnology. Small firms do not usually have the resources to withstand the long delays and associated uncertainties.

Take the case of the Canadian Radio-Television and Telecommunications Commission. In November 1984 the CRTC recognized the need to license small-community cable service, but action took 15 months, during which there was virtually no market for CATV equipment in Canada. Having to wait that long, eight supply companies gave up. Similarly, it took 30 months for the CRTC to act on the announced intention by the Minister of Communications to encourage private ownership of earth stations for corporate networks.

The policy task is to ensure that red tape does not either stifle the initiative or undermine the survival of technology-based small firms. There should be a premium on flexibility and responsiveness.

Defence-industry research

Canada's defence industry is very outward-looking, shaped largely with the North American market in mind. But current emphasis, as promoted by the June 1987 white paper on defence policy, is to make the industry more inward-looking and to secure sources of supply of key items for the Canadian Forces. This policy will be tough to achieve,⁷ and it may prove very costly if it fails to generate civilian spin-offs, becomes hooked on complexity and sophisticated hardware, and absorbs more of our already scarce first-rate technical experts. It also involves the question of whether military spending is an efficient vehicle for the government's economic development designs.⁸

Since 1959 the defence industry has had virtually free trade within North America. A more inward-looking stance will almost certainly require an R&D capability, depending on the niche chosen to serve the Canadian Forces.

Much of the R&D carried out by the Department of National Defence (DND) is devoted to maintaining a technology base. But DND is increasingly funding and farming out R&D to industry. In stepping up production of military goods, the government in recent years has supported leading companies and technologies, particularly in aerospace, electronics, and materials. Canada's 2000-or-so defence firms are mostly small and focus on components and subsystems. Some spend a large (10 per cent to 15 per cent) part of revenues on R&D. Generally it is the strength of export sales to the United States that helps maintain

their high R&D performance. Four further points regarding defence warrant mention.

First, regarding the FTA, the modest improvements in government procurement policies did not significantly affect the defence sector. The two sides have agreed to continue discussions on further liberalization. Second, although there is virtual free trade in defence goods, the big and important exclusion is the American small business set-asides program. It is a significant impediment to small Canadian technology-intensive firms that seek American defence contracts.

Third, Canadian firms may soon have a big advantage over European firms in obtaining American defence contracts under a recently introduced American trade bill. The sponsor has agreed to exempt Canada from the bill's most protectionist provisions,⁹ and the legislation also aims to eliminate certain types of industrial offsets from military contracts, a mechanism Canada was one of the first to develop. The intent is to negotiate bilateral deals outlawing the practice. Canada is now downplaying direct offsets (such as the straight purchase of goods that may or may not be related to the original military project) in favour of such industrial benefits as technology transfers, joint ventures, and coproduction arrangements.

The fourth point regarding defence is the opportunity that increasingly arises from the American policy of creating second sources for large production contracts, to ensure supply and competitive pricing.¹⁰ In some cases the second source will work to the original manufacturer's designs. In others, the second source may be involved in an early stage with the main contractor and may help develop the product before becoming a competing second source. This American policy may open a significant opportunity for Canadian contractors, which at best are medium-sized, because the lead companies would generally see a Canadian second source as being less of a threat to them than another giant American company.

The restoration in Canada of the once very popular Defence Industries Research program, axed in 1975, should help industrial R&D. Based on unsolicited proposals, the program provides grants to industry for cost-sharing R&D projects of military interest. Several trade associations had pressed the government to restore the program, both to assist industry R&D and, more particularly, to encourage closer links between industry and the six defence research laboratories. The program

could help Canadian companies build a better long-term capability not just for Canadian defence contracts, but also for American ones.

The government restored the program in early 1988. The grants, designed to increase to \$15 million a year by 1991, will be oriented toward applied research in smaller projects.

A civilian equivalent to DIPP

Canada's main performers of industrial R&D tend currently to be very hesitant to tackle more than one or two promising large projects. This is particularly so if the projects cost more than \$25 million a year and no return cash flow is expected for more than five years. There is a major "risk overhang" in such large projects. Present government incentives and programs, excluding the Defence Industries Productivity Program (DIPP), appear not to compensate sufficiently for the level of risk. DIPP allows the government to invest in such technology initiatives, but only in the aerospace and defence-related industries. To encourage more industrial R&D by the present large performers, there may be an advantage in supporting major civilian projects by a parallel program to DIPP. Supporting just two or three such major projects each year might be more effective than supporting the creation of several dozen new technology-based firms.

Chapter 7

Issues for the 1990s: What's Emerging?

A variety of issues that impinge on or directly relate to the development and diffusion of industrial technology are looming. Some are irritants; others may become major concerns, placing Canada's access to certain types of technology in jeopardy. They involve export controls and industrial espionage, technology protectionism and expansionism, counterfeiting and piracy, and foreign investment.

Technical data, export controls, and industrial espionage

Canada has become a target for the theft or diversion of sensitive S&T secrets. Our precautions are not up to scratch. Making them so is becoming a major new priority — the more so if the free trade deal broadens access to American civilian and military procurement and if Canada strengthens the links between national defence and industrial development. As the chairman of Canada's Security Intelligence Review Committee recently pointed out: "Canada has a duty to safeguard borrowed as well as home grown science and technology.... We need a stronger, more aggressive intelligence capacity to protect sensitive Canadian military, scientific and industrial technology."¹ It will take special expertise in science and law and that will take time to nourish.

Access to, and protection of, American-sourced technology is crucial for Canadians. There are two American statutes that regulate the export and dissemination of technical data regardless of their internal source. The controls are part of American efforts to inhibit the transfer of advanced, militarily important technology from the United States to the Soviet Union and other Warsaw Pact nations. The costs to business of the controls are substantial. Furthermore, the controls affect American and other firms that do business outside the territory of the United States.

Canadian firms encounter problems not so much with the intent of the American controls, as with their definitions (including the extremely broad definition of technical data) and implementation. The Commodity Control List, the Munitions List, and the Militarily Critical Technologies

List are long and unselective; it is virtually impossible to identify an area of science or technology as having only military or only commercial applications. Moreover, the restriction of technology flows requires a degree of control over the worldwide technical enterprise that is beyond achievement.² The precautions are far from leakproof. Exporting firms and participating foreign governments alike often resent the system, but living with such controls will become more important.

The difficulties faced in trying to prevent the outflow of new American technology to other countries is shown by studies on the rapidity with which new industrial technology leaks to rival firms and is imitated. One investigation of 100 American firms found that rivals become aware of a decision on development within about 12 to 18 months, on the average, and detailed information on a new product or process generally leaks out within about a year.³ If it takes, as is typical in many industries, three years or more before a major new product or process is developed and commercialized, there is a better-than-even chance the decision will have leaked out before the innovation project is half-completed.

Technology protectionism and expansionism

Canada's ready access to foreign technology may be in further jeopardy. Some new and disturbing forms of technology protectionism are beginning to emerge between developed countries. Canada may be caught up in the backswell of increasing competitive pressure between the United States, Europe, and Japan, particularly as defenders of intellectual property are using litigation as a competitive weapon or are becoming far more selective in licensing their technology.

Much is said on the importance of the free flow of scientists and S&T information across borders and of effective protection of intellectual property rights for commercial applications. The blurring of the distinction between science and technology, the rapid internationalization of R&D, and the growing industrialization of basic research together raise questions about the extent to which this free flow is being disrupted. Will national originators of key ideas, information, and innovations (say American universities working under contract with Japanese firms) necessarily be significant beneficiaries, especially if contracts restrict the use of the research results? R&D protectionism is, even for the Americans, becoming a disturbing reality. But the primary losers from the withholding of S&T knowledge from

the international public are the small, developed nations. Advanced-technology research has become so demanding and costly that it is beyond the capabilities, in many cases, of even a wealthy small country.⁴

Serious concerns are surfacing in Japan and Europe that curbs are growing, in the United States especially, on the free flow of S&T. The fear is that there are within the United States intensive political pressures to impose on key government and civilian technology the same curbs now on military technology, including protection of "sensitive but unclassified" government information.⁵ Such anxieties are fuelling a drive in Japan to promote technology expansionism — Japanese firms are tending to rely less on technology licensing and the traditional free flow of scientific information and more on taking equity in American companies or on undertaking joint R&D ventures abroad, to learn about emerging science and technology.⁶

Technology expansionism in the form of joint R&D ventures may have its dark side. Some European senior executives consider the Japanese partners are contributing little while taking a lot. They are sounding the alarm against one-sided, joint-R&D ventures and what they perceive to be unfair trading practices.⁷

There is concern about access to government R&D. For instance, indications are that the American government will re-craft its five-year bilateral S&T agreements to emphasize, as in the 1988 agreement with Japan, "equitable" cooperation. This means the United States will be able to tap into the government-funded R&D establishments of other countries, to gain access to their intellectual property, and to establish a more balanced, two-way flow of information and researchers.

There is growing adverse comment, especially from Americans, on the level of Japanese contributions to the basic research that underpins much of modern technological advance. The need is seen for equitable contributions. Starting at a 1987 OECD meeting of science and technology ministers, the United States has promoted proposals intended to lead to common principles of scientific cooperation, generally accepted practices among nations, and bilateral agreements. The equitable contribution would be in supporting basic research, maintaining facilities, and training the next generation of scientists and engineers. The proposals also aimed at unrestricted access to technologies, subject to universal protection of intellectual property rights.⁸

Technology counterfeiting and piracy

In riding the tiger of technology, the developed countries increasingly confront less-developed countries (LDCs) (as well as many international development agencies) who view technology, in effect, as a free good, a part of the universal heritage of all humankind. Whereas developed countries are caught up in a race for economic growth driven by proprietary technology, many LDCs urge dismantling the world patent system, releasing all proprietary knowledge, and ensuring its low-cost transfer to LDCs.

The current technology-transfer policies of some leading LDCs — and some Eastern Bloc countries — deny the profits of innovation to foreigners whose technology they pirate. These policies are having an increasingly negative effect on technological innovation in developed countries. Product counterfeiting has grown dramatically.⁹ There is little agreement on the actual size of the counterfeit market, but estimates range from about 2 per cent to as much as 5 per cent of world trade. And technology-driven industries, from pharmaceuticals to computers, are particularly susceptible.¹⁰ Estimates of job losses in the United States are as high as 750 000 annually. Estimates for Canada are that in the computer-software industry alone several thousand jobs are lost to counterfeiting each year.

The piracy of intellectual property through product counterfeiting is becoming a critical issue, one of increasing concern to business. It is on the agenda of the current round of General Agreement on Tariffs and Trade negotiations. These negotiations must address the present gaps in international conventions, the lack of coverage by regulations in many countries, and the deficiencies in national enforcement.¹¹ Effective ways must be found to protect intellectual property and deter counterfeiting. That will require addressing the broader issues of fairness in the existing world economic order.

Foreign investment

The extent of foreign investment in Canada and the performance of foreign subsidiaries will likely continue to be an issue that refuses to go away, a source of sensitivity in the 1990s. Canadian investment abroad has been growing rapidly; by 1984, 0.4 per cent of the American GDP was accounted for by Canadian-owned enterprises. But that pales beside the 15 per cent or more of Canadian GDP accounted for by

American-controlled businesses. In the non-financial sectors, foreign-controlled corporations had nearly 30 per cent of sales and more than 43 per cent of profits in Canada.

Nineteen eighty-six proved a benchmark year for Canada. Foreign investment here has for many decades been synonymous with American investment. That year, the total non-American foreign investment, at \$131 billion, finally exceeded the total American investment here of \$128 billion. However, American direct investment, in controlled branch plants, totalled \$68 billion, still more than double the \$25 billion of direct investment by other foreigners.

Fear for Canada's future is fuelled by the continuing high rate of foreign takeovers. In 1986, \$6.8 billion of foreign direct investment came to Canada, mainly to finance takeovers, albeit frequently of subsidiaries that were already foreign-owned. Added to that was about \$4.5 billion of investment by foreign subsidiaries already here, less \$4.8 billion in dividends repatriated to foreign owners. That was at a time of an open-door policy, but before the free-trade negotiations at which our neighbour successfully pressed for further concessions on foreign direct investment.

Critics of Investment Canada note that it has not turned down a single foreign acquisition, and they point to the failure fully to implement agreements signed with those making the takeovers. Its seemingly lax stance suggests an open season for foreigners interested in controlling key sectors of the Canadian economy. A perennial issue is whether the agency is protecting Canada's long-term interests and whether its mandate should be extended to cases — such as new and small, technology-based firms that have received taxpayer support — that fall below the \$5 million category subject to review.

The fact is that many countries have become more open to foreign investment because of the globalization of trade and investment. But other countries have yet to face the degree of foreign ownership and control that prevail in Canada. Where rates of foreign ownership have rapidly increased, even to levels far below those in Canada, similar concerns have been raised and in some cases action taken. Sweden, for instance, has been scrutinizing foreign acquisitions of domestic firms for about four years. It is ironic, too, that increasing foreign ownership of the American economy — now about 10 per cent of manufacturing and 15 per cent of the oil industry — has stimulated fears about the threat to political and economic sovereignty and the possible loss of important

technologies such as photovoltaics. It has also generated moves for legislation to halt it.¹² Some states, Delaware for instance, already have anti-takeover legislation, just as some countries, such as Switzerland, have laws that effectively protect major firms from foreign takeovers by restricting shareholders' rights and limiting foreigners' rights to buy property.

Trade in professional services

The information economy heightens the importance of trade in professional services, including the services of scientists, engineers, architects, and doctors. Canada has strengths in many professional services, especially consulting engineering. Trade in these services is not well documented, but it is undoubtedly growing. It is hampered by restrictions, typically national regulations governing the professions, levels of competition tolerated, immigration policies, subsidies and government procurement practices, as well as constraints on the transfer of information and access to local databases. Government export subsidies are a major source of unfair competition in areas such as consulting engineering.¹³

Many benefits and costs arise from liberalizing trade in services. It is an area in which the stakes are high for Canada's scientists and engineers and will warrant close attention in the coming decade.

Environmental concerns

By far the major emerging issue for the 1990s is the crucial need for remedial and non-polluting technologies. In light of the hazardous state of the world environment and increasing environmental concerns in Canada, there is likely to be renewed radicalism in the environmental movement. Emerging technologies will probably be scrutinized more to assess their positive and negative environmental impacts. As the World Commission on Environment and Development points out, "Emerging technologies offer the promise of higher productivity, increased efficiency, and decreased pollution, but many bring risks of new toxic chemicals and wastes and of major accidents of a type and scale beyond present coping mechanisms."¹⁴

The urgent need to shift toward sustainable development will lead both to disturbing threats and to substantial opportunities in the development and diffusion of industrial technology in the 1990s.¹⁵ For

instance, a strong commitment to cleaning up our water resources should open opportunities for Canada to develop an internationally competitive industry, based on our first-rate water science, to produce clean-water technologies.¹⁶

Other issues

In preparing this report, the author asked editors of trade journals and leaders in Canada's trade associations what S&T issues they thought would be pertinent in the 1990s. Among those not raised earlier are:

- Staffing centres of excellence — will competition for limited resources affect their viability?
- The need to target enabling technologies that have a multiplier effect, thereby obtaining a better result than general support to S&T. How can broad target areas be jointly recognized by industry and government?
- More funding to universities to safeguard basic scientific and technical resources, and better links between universities and industry. In an information-based economy, universities become a primary resource;
- Instilling a more positive public attitude toward S&T and raising awareness of the crucial role of industrial R&D;
- More vigorous contracting out by government to enhance sophistication of the workplace and raise skill levels;
- More flexible policies for employment and worker adjustment to encourage a mobile, adaptable workforce that can accommodate necessary technological changes;
- Research support increasingly needs to be designed to avoid foreign countervail actions; and
- Optimum use of federal funds to expand cooperative R&D.

Chapter 8

Strengthening the Strategy: Reinforcing Self-Help

Canada faces an enormous challenge to develop and harness S&T for industrial renewal and thus become more competitive in global markets in a period of fundamental changes to the world economy. The country is beginning to move in the right direction. It is now giving priority to this overriding issue and has over the past decade taken many appropriate steps at all levels of government. But although governments are increasingly working with the private sector to improve performance, the pace and scale of the effort fall far short of what is required. Canada still lacks the national singleness of purpose that would strengthen its global competitiveness; we need a culture that values and rewards achievements in science, technology, and innovation.

There are still many issues to debate, barriers to overcome, resources to reallocate, links to forge, threats to address, and opportunities to grasp. Some issues, from government procurement to increasing industrial R&D, have been addressed by multipartite advisory bodies such as the National Advisory Board on Science and Technology and the Premier's Council of Ontario; most await actions that will lead to successful integration into federal and provincial S&T policy.

This report identifies key areas for action to strengthen the emerging strategy to enhance S&T-based industrial renewal. Some actions are crucial; others are important, but will make only a minor contribution without significant progress in the following six priority areas:

- A more supportive governmental financial policy;
- Far greater self-help efforts in the management of technology by the private sector;
- More Canadian world-class companies;
- New mechanisms to identify and generate consensus on sectoral innovation strategies;
- More-productive consultation about mechanisms for choosing priorities; and
- The allocation of significant additional resources to major programs that are of high priority.

The Science Council of Canada agreed that these are key priority areas. Building on this background study, its November 1988 statement *Gearing Up for Global Markets: From Industry Challenge to Industry Commitment* put forward recommendations for action by the private sector and governments in all six areas, which are reviewed below.

Governmental financial policy

Tax reform has weakened the role of tax instruments in supporting and inducing the investment by Canadian firms in industrial R&D. Although tax incentives in Canada remain a significantly more important instrument of public support for R&D than they are among most of our competitors, recent tax changes present the prospect of stifling this engine for growth. Canada's overall government support for industrial R&D, as a proportion of gross domestic product, is a meagre one-third the level of that in France and West Germany and one-sixth of that in the United States.

There are encouraging signs of action to improve the use of some non-tax instruments, an important one being movement toward agreement on eliminating interprovincial barriers to governmental procurement. But there is still a need to refine the federal use of tax and non-tax instruments in a strategy for raising levels of industrial R&D in Canada. Remember, however, that improving the scope of such support will not in itself be much help if Canadian managers continue to place so little emphasis on technology and innovation. What is needed now is to raise the level of demand by senior management for strategic investment in industrial R&D.

Self-help and management of technology: the hidden competitive advantage

Canada ranks among the weakest of developed countries in the management of technology. Our most immediate S&T problems are the inability of managers to develop and apply technology to make a profit, the low rank within managerial hierarchies for those with technological expertise, and the relatively poor rewards for these people. Many managers are aware of this failing. In one recent survey of 100 Canadian companies, 60 per cent of managers indicated dissatisfaction with their ability to innovate.¹

Industry is unlikely to make major increases in technological capability and industrial R&D without, on the one hand, significant changes in attitudes, capabilities, and commitment by boards of directors and chief executive officers and, on the other, risk-sharing and more guidance in choosing priorities from governments.

It is crucial that industry be encouraged to help itself. Shorter product life cycles, speedier innovations in process technologies, greater concern for quality, and constant competitive pressures create new cost structures, investment justifications, and strategic priorities. Many companies need to see more clearly the place of technology in the total strategy of the firm.²

Unfortunately, too many boards do not see the need to improve. And even with the best of intentions, many directors and senior managers lack experience in dealing with technology, especially in organizing and intensively managing corporate R&D and technology renewal.³ The Canadian Manufacturers' Association has pointed out that too many managers are failing to allocate the resources to acquire and integrate the technological capabilities needed for their strategic and operational goals. Most do not even have a strategic plan.

Much higher standards of performance are expected from today's boards of directors, who are being held more closely to account for corporate results.⁴ Canada's corporate boardrooms are changing; younger directors from more varied career backgrounds are being appointed. These directors are often below chief executive officer rank, have special expertise, and occupy fewer directorships. What is now required is to ensure that boards also have members who are aware of, if not expert in, relevant areas of technology and know what innovations competitors are making based on new applications of existing technology. This will enable the boards to anticipate technology threats, shocks, and opportunities.

Management consultants find that few Canadian companies take technology into account when deciding on their strategies. Too frequently, major technological choices are treated as tactical rather than strategic decisions. Or they are viewed largely in isolation, as the concern of the R&D department, for the few that have such a department. But for new technology to offer competitive leverage, a variety of related management conditions must be in place.

The proper exploitation of technology must move to the top of the agendas of Canada's directors and senior executives. Business leaders

must also collaborate with government and university business schools in the researching and teaching of technology management. That will require stronger links between engineering, science, and management disciplines. Canadian firms will thus develop the technological ability to shape and accomplish their strategic and operational objectives.

Also, a deeper understanding is required of how to make the capital decisions so important in the application of new technology. It is particularly necessary to overcome the narrow accounting vision that bases capital decisions on classical return-on-investment calculations and seeks to recover funds only from savings (especially labour savings), not from gains in business. As many American firms are now finding, much automation does not pay off, in part because conventional accounting leads managers to fund the wrong investments.⁵

To help bridge the gap between university and business cultures and improve the management of small firms and their ability to receive and exploit technology, the presidents of small, technology-based firms should cooperate with university researchers to build research and teaching capability in the management of technology in small business.

Similarly, for faculty to contribute useful applied research to small business, an important step would be to broaden the definition of university sabbaticals and ensure there is due merit awarded. That will require reassessment of the senior industrial fellowship program administered by the Natural Sciences and Engineering Research Council.

In the past few years Canadian universities have been active in addressing business needs in the management of technology. There is still much to do.⁶ Two areas warrant immediate attention by universities. First, there are indications that business would like to see a better match between its needs and the skills developed at universities, particularly among engineers. What business needs is an emphasis on engineering creativity as well as on skills in project management and financial control. Second, there is an immediate need by business for continuing education in the management of technology, yet continuing education receives a low priority for university funding. Governments should target funds to assist universities and colleges to provide programs of continuing education in technology management, to bring in distinguished experts, and build domestic and foreign networks of excellence.

Small Canadian manufacturing firms frequently lack engineering expertise. That is thought to restrain their capacity to keep abreast of best technology practices, slow their pace of technology adoption, and limit their full and proper use of the many sources of technology advice and support. Small-business associations should work with professional engineering associations to develop a small-business awareness campaign indicating why and how Canadian small business can benefit from greater employment of engineers and from greater technological cooperation.

One feature that warrants emphasis is the need for effective technology networks for product development, process development, and procurement. These networks involve the informal trading of know-how and close interaction with product users or suppliers.⁷ Network building is a long-term investment; firms need to connect their technical abilities and R&D resources with a wide variety of other sources, internal and external, domestic and international, including suppliers, customers, and universities. Smaller firms also must learn to make good use of federal and provincial government laboratories and mechanisms — such as, for instance, the Technology Inflow Program and the technology development officers stationed abroad to support Canadian business needs.

Another feature that deserves emphasis is that the drive to diversify the Canadian economy and develop higher-value-added products through technological progress must be linked to customer needs. Modern research shows that product advantage is a dominant factor in the success, as measured by financial performance and market share, of new products — that superiority in the eyes of the customer is paramount.⁸ The buyer seeks a high-quality product that delivers unique benefits and solves or performs a unique task. Product advantage, then, is customer- rather than technology-based, and it is understanding what the customer views as a superior product that needs to drive the R&D and design processes. And increasingly in our relatively small and open economy, the dominant customer is the foreign customer. That means that thorough investigation of foreign markets is vital when defining requirements for domestic research, development, and design. Corporate success in the new environment of intense, technology-based competition depends heavily on effectively coordinating R&D, marketing, and the customer.⁹

It is costly for Canadian firms to do market research on their own, and there are serious gaps in information about opportunities in many foreign markets. This is especially true of Third World markets in Asia, which are growing twice as fast as markets in industrialized nations. A sensible proposal, put forward recently by the Conference Board of Canada, is for storefront offices in foreign countries to advise on local business practices, joint-venture arrangements, and sources of financing. Government support for technical missions linked to these storefront offices might provide the necessary initial momentum for Canada's technology-oriented firms to fill in the information gaps that limit their capacity to thrust into such markets.

Similarly, to build foreign technology networks and to understand market needs and grasp the opportunities abroad frequently requires the ability to speak foreign languages and overcome cultural gaps. Canada has been slow to develop global trading skills. Ontario has recently made a start with its Centre of International Business. Governments, in consultation with the private sector, might usefully target particular markets, especially Japan, rather than spread resources too thinly.¹⁰ The federal and provincial governments should jointly fund a program for graduate engineers to learn designated foreign languages and study abroad.

World-class companies

Globalization of Canadian industry will represent a major challenge in the 1990s. The Canadian industrial mix mainly comprises a relatively large and vibrant, Canadian-owned, small-business sector, many medium-sized and large, limited-product-line, Canadian-owned enterprises, and many foreign-owned subsidiaries, some with world-product mandates or specialized North American missions, but most with a truncated range of functions. In comparison with such countries as the Netherlands, Sweden, and Switzerland, the Canadian industrial mix lacks indigenous, science-based, threshold firms and multinationals, including diversified companies with the expertise and other resources to operate globally.¹¹ Increasingly, globalization will require production as well as marketing at strategic locations around the world.

In the new and uncertain global ballgame of high interdependency between economies, Canada should strive to develop and support dynamic, world-class, small companies. Many of these could be

expected to develop into domestically based firms big enough to operate efficiently and effectively as multinational enterprises and to own the complementary assets that enable the innovative firm to profit from innovation and to spread innovative risks. Few small companies, however nimble, can survive long against stable, concentrated, and, frequently, protected industrial alliances.

One way to achieve such world-class companies is for the private sector, with the acceptance if not support of Canadian governments, to build diversified firms that are more carefully structured around technological or market skills. The signing of a free trade agreement with the United States can only reinforce the need. It will be essential to broaden our horizons beyond our own backyards.

As one astute observer recently pointed out, regarding diversified firms:

...such organizations can provide two of the strengths that have accounted so significantly for the German and Japanese success stories. The first strength is concentration on the long-term rate of return rather than living quarter by quarter. The second is the synergy of highly qualified, entrepreneurial management — people who have grown up with their companies, know them well and who are not being second-guessed from above but who are being supported positively from the centre. The synergy is one of the factors to be considered in looking at the contribution such organizations can make to Canada's economic welfare. Synergy can provide added value in terms of an overall entrepreneurial drive, a stable long-term earnings base to attract capital and the capacity to make capital investments in individual units.¹²

Another way is to seek niche markets in Canada that have a broad application in world markets. Canada's information-technology firms are attempting to do this, particularly through extensive use of supplier-development programs.¹³ They find that niche marketing can be done by firms of all sizes, but smaller firms often lack the marketing and financing resources to do so easily. Becoming a supplier to leading firms can open windows to world markets, with the supplier frequently benefiting from access to technology and management techniques provided by leading firms.

Many multinationals are moving toward a new form of organization for their global business and are learning how to exploit the strengths of their subsidiaries and use them on a global scale.¹⁴ Subsidiaries are in

some cases becoming sources of information and expertise on which to build competitive advantage; those with specialized missions and world-product mandates increasingly depend on a network of supplier firms for sophisticated parts and components.

The trend is more and more to lodging key quality-control activities in the supplier firm, to involving the supplier firm in initial design, and to the purchase of complex subassemblies as well as single parts or components.... In many cases, it is advantageous for supplier firms to be located in geographic proximity to the lead firm carrying out a mandate or mission. Geographic closeness permits easier interaction and cooperation in development and production. It simplifies the integration of supplier and customer schedules to permit both the economies of real Just-In-Time manufacturing.¹⁵

A strong network of supplier firms strengthens the competitive position of the subsidiary and enhances the likelihood that it will earn new mandates or missions, and the suppliers have the opportunity to become threshold firms and science-based, indigenous multinationals.

One action that could help create world-class companies has been proposed in slightly different forms by both the National Advisory Board on Science and Technology and the Premier's Council in Ontario. That is a special risk-sharing fund to help medium-sized technology companies finance the development, production, and marketing of new products.

To move in this direction requires that Canada's leading financiers and industrialists accept the need to do so. Public fears of monopolistic trends in the creation of world-class companies can be allayed by reference to the Competition Act. The major need is to stimulate a national debate on this topic, to alert and involve business leaders.

Sectoral innovation strategies

Canada faces inherent tensions between the demands of regions and the demands of sectors.¹⁶ Our governments are elected on a territorial basis, which can be a handicap when they have to deal with many sectoral needs and opportunities. Nor does it help when sectors are represented by too many or too weak associations, as these have proved inappropriate vehicles to help government make and carry out policy.

To stimulate the process by which government helps the private sector help itself, the Science Council recently recommended that sectoral R&D targets be set and sectoral innovation strategies be

developed. This calls for close, ongoing consultation within the private sector and between it and government to build consensus on priorities and agendas for S&T action.¹⁷ An important start could be made with the resource and resource-based industries. The success of the initiative will clearly depend on whether the private sector is alert to technological opportunities and needs and whether it can readily achieve a consensus on where to direct resources, including those for precompetitive research in the universities.¹⁸

Productive consultation and selectivity

Limited resources heighten the need to be selective in R&D spending. Economic renewal in the 1990s will be best achieved by those countries that can speedily and efficiently allocate or reallocate resources to innovative activities and sunrise sectors. An important part of this process is sectoral strategies. They require new organizations or the strengthening of existing ones to make broader choices of priorities between sectors and to target investment in overlapping areas, such as technologies common to several industries.

Canada has yet to respond satisfactorily to the need for concentration of its S&T resources. Limited resources are at present spread too thinly across the spectrum of opportunities. And existing institutions and mechanisms for building consensus lack legitimacy to act alone and the authority to speak for wider interest groups or regions. So long as the country remains highly balkanized and resorts to divisive forms of executive federalism, it is unlikely that consultation in itself will prove productive in helping to shape decisions or in leading to effective consensus on priorities.

The Science Council of Canada expressed its concern on this issue in 1984. It pointed out that:

Canadian institutions (despite the existence of common interests, shared goals, and similar values among Canadians across the country) excessively emphasize competition. Without a process to accommodate their differences, alienation often prevails among business, labour, and government, and between levels of government. Without workable consensus mechanisms to integrate and reconcile different interests across the country, Canadians will be seriously handicapped in global competition.¹⁹

In the past few years there has been growing attention to this urgent problem.²⁰ But there has not been much effective action. The private

sector has started to contribute by reducing its fragmentation, which hampers the building of consensus on priorities. The need is for better input by the private sector to government decisions on targeting.

Major programs

Although self-help is the best help, in itself it is not likely to be anywhere near enough. There are important gaps in the Canadian industrial structure and infrastructure. Government can fill some of the gaps by targeting its spending on certain programs, after widespread discussion with the private sector. Two major programs that warrant such attention are engineering and industrial design, and environmental technologies.

Engineering and industrial design

A basic reason that many Canadian companies tend to buy virtually all their technology is that they need not or cannot perform engineering and industrial design. This habit has in turn helped stunt their design capabilities, so that relatively few can improve on the imported technology or create new products. Speeding the technology diffusion process will not overcome this problem.

The problem is more insidious. Take the case of domestic developers of new materials such as ceramics. Many Canadian companies that might use ceramics do not perform any engineering design. As a result, suppliers cannot form with users the kind of relationship that would produce feedback useful in developing new materials with new properties. The suppliers thus are at a disadvantage with their foreign competitors.

Canada has failed to develop the collective capacity to transform R&D quickly into world-class goods by integrating design with fabrication and manufacturing. Yet, arguably, it is less the basic inventions that create social wealth than the application of design and production expertise, as the Japanese are now so convincingly showing the world. Without the integrated design and production capability, the fruits of research too readily take seed abroad. Product-design teams must work with manufacturing engineers to perfect product lines and make incremental product improvement.

It is high time for serious reconsideration of how public policies can strengthen industrial and engineering design capability in the private sector and modernize the engineering and technology resources in our

universities and colleges. That might be achieved, in part, by imaginative major programs. One, for instance, might focus on home-based care systems, driven by public funding and innovative procurement, to address the serious problems emerging for the care of our ageing population — surely a worthy challenge.²¹ Others might be large-scale industry projects built around consortia of companies in support of public educational and environmental programs.

Environmental technologies

Global concern to clean up the environment, if translated into action, may create major opportunities. In the growing movement toward sustainable domestic and global development, environmental and economic concerns must go hand in hand. The National Task Force on Environment and Economy recommends Canada move away from its previous essentially “remedial and reactive” approach to environmental management and toward “anticipate and prevent.”²² It rightly urges an emphasis on research into and promotion of waste disposal and recycling, as well as environmental clean-up and enhancement technologies and techniques.

One way to achieve that emphasis might be through a major program on remedial and clean-environment technologies. The project could be built around federal and provincial government enabling technology contracts, funded up to 100 per cent. The contracts would require a verifiable demonstration of technology to meet performance requirements established by governments. The program should also encourage a network to enable diffusion of environmental technology, provide recognition to successful performers, and promote Canadian participation in international trade fairs.

Beyond these six priority areas for action there are several other areas that warrant initiatives: precompetitive research and cooperative R&D; university-industry cooperation; new technology-based firms, entrepreneurship and small business; strategic partnerships; and ISTC, regions and provinces. These are examined below.

Precompetitive research and cooperative R&D

Research is becoming more expensive — the funds at risk are greater. Companies accordingly are seeking to pool resources and make new R&D alliances. Agreements between industry, government, and

universities for collaborative research are proliferating — especially in the United States (despite the shallow roots of economic cooperation in American society), where they signal a fundamental realignment of institutions. They respond to the urgent need to accelerate growth in productivity and raise competitiveness.

Cooperative R&D, though still limited, has also grown considerably in Canada. During recent years there has been collaboration between firms supported by the National Research Council's Industrial Research Assistance Program and the small number of industry research associations, between firms and the many government laboratories, industrial technology centres and contract R&D organizations (including provincial research organizations), and between firms that use such facilities as research parks or business incubators.

One innovative approach, which the National Research Council has helped develop, is technology circles.²³ They avoid the problems of competition by bringing together groups of non-competing firms that have a strong interest in a particular technology. Members develop products together, coordinating their contributions.

Precompetitive research, usually in conjunction with universities, has also been increasing. This is research in emerging areas not yet developed sufficiently to identify products and processes. The research is frequently in technologies of common interest such as advanced materials, biotechnologies, or artificial intelligence.

These generic technologies could be extremely important. It is not surprising therefore that federal and provincial governments are inundated with internal and external proposals to support cooperative research in them. For instance, a variety of federal agencies may have an interest in any given generic technology; this leads to confusion as to which federal agency is responsible and, for the private sector, whom to approach in government for assistance. The time has come for clarification, one result of this being that any one applicant will not be able to stack up grants from various federal and provincial agencies. It might be useful for the Department of Industry, Science, and Technology to be the lead agency responsible for coordinating policy and delivery vehicles for concentrating government support for cooperative and precompetitive research.

University-industry cooperation

Many countries, in recent years, have increased university-industry links as science has become big business. Successful cooperation of this type may prove crucial for Canada, given the paucity of industrial R&D and the urgency of strengthening the technology of our resource industries and diversifying into higher-value-added products.

Yet such cooperation in Canada has been slow. Not much university research is funded by the private sector — an estimated less than 1 per cent of Canadian R&D in science and technology and less than the corporate-sponsored research at just one American university, the Massachusetts Institute of Technology (MIT).

Much more cooperation is called for. The constraint is surely not cost. With present tax rates and research tax credits, university research for a corporation is very attractive — rarely costing more than 40 cents on a dollar, if that. And Canadian costs are only half as much or less than those in the United States. Neither is there any lack of federal or provincial programs to promote closer ties.

The constraints seem elsewhere — in motivations, attitude, and understanding. Enhancing cooperation may require some change in the motivation and reward systems of universities. The attitudes of corporate executives also must change, especially their understanding of the capabilities of universities. The former change is addressed in the Science Council's report, *Winning in a World Economy*;²⁴ the latter change should, in part, occur as the Canadian business community understands more of technology issues and becomes expert in the management of technology.

One way to strengthen cooperation and enhance the transfer of technology is for companies to arrange for their scientists and engineers to work temporarily in university labs. Japanese companies have been doing this with American universities. As one MIT professor points out: "The Japanese company usually sends one of its staff members here as a visiting scientist. The person will be absolutely first-rate and make a real contribution to the project. Normally the U.S. company doesn't send anyone. It just waits for the report."²⁵ Canadian companies should review the benefits of sending staff to work as visiting scientists in university laboratories.

New technology-based firms, entrepreneurship, and small business

Small and medium-sized technology-based firms have a special role in Canada. It is on them that Canada increasingly must rely to translate ideas and concepts into new, viable products and services. It is crucial that federal and provincial governments cooperate to support the growth of many more such innovative firms.

Recent experience reveals, in western Europe as well as in the United States, a massive increase in the number of new, technology-based manufacturing and service firms. They are emerging especially in information technology and biotechnology, where entry costs seem low and innovation is knowledge-intensive.

Canadian federal, provincial, and most lower-tier governments aim to foster entrepreneurship, including technical entrepreneurship. This first requires a favourable economic climate. Recent federal budgets, until the latest tax reform, are broadly recognized to have improved that climate, providing many helpful measures for small business. Also helping small business were measures such as the Quebec Stock Savings Plan. But governments can and should do much more, especially in technical entrepreneurship. The federal government has recognized the problem and has taken tentative steps in a national entrepreneurship policy. And Ontario recently set up six centres to teach the appropriate skills.

The number of budding technical entrepreneurs might significantly increase if more Canadian universities provided leadership, training, and R&D facilities to foster entrepreneurship as a career option. A growing body of thought holds that entrepreneurship can be learned and that innovation can be taught — perhaps through innovation counselling to small and medium-sized firms.²⁶

Nationwide there is a plethora of government programs that offer small business some form of managerial or financial assistance. Yet too often the programs operate in isolation. Better cooperation between departments and between levels of government remains a continuing concern. Efforts to build closer links, for instance, between the National Research Council's Industrial Research Assistance Program and agencies or institutions that provide true risk capital are to be applauded. They could address undercapitalization, a continuing key weakness of small technology-based firms. Many such firms need a better cash flow or equity financing, a problem not well addressed outside major

metropolitan areas. A key requirement, frequently noted, is for more long-term risk capital and more-patient investors.

Technical entrepreneurs also have difficulty in securing funding to start up firms. Many, no doubt, do not have sound proposals. Capital is no panacea if the real problem lies elsewhere. But evidence is accumulating that investors in the organized venture-capital market, as well as the Federal Business Development Bank, shun small, start-up companies, partly because the financing requested is too small to interest them.²⁷

The federal government, according to the Minister of State for Small Business, is generally happy with its support for the pre-start-up and start-up phases of new enterprises. But he agrees on the need to refine and better target the programs. All the provincial governments in recent years have sponsored programs to increase the venture capital available to small business. Yet surveys indicate that, although these programs have focused on seed or start-up investments, few investments are oriented to technology-intensive firms. The need remains to improve financing of technology-intensive start-ups. It takes political courage and commitment to support a large number of such start-ups when many of them are likely to fail. But that is what is required to attain, eventually, a few big winners.

Other countries have shown such commitment and courage. They recognize that such small, new firms, which usually exist in symbiosis with large firms, are often the spearhead of technical advance. Many European governments have introduced policies to encourage new, technology-based firms. A West German scheme, for instance, provides grants of up to 90 per cent of the costs of the inception phase and up to 75 per cent of the R&D expenditures incurred. Moreover, it guarantees up to 80 per cent bank credit, with a maximum of DM 2 million, for the production and commercialization phases. The program is, in effect, a social experiment to stimulate technical entrepreneurship and fill a void before conventional capital is available. This federal German program is complemented by similar programs at the state level.²⁸

The vitality of Canadian small business will continue to be important in creating jobs and filling market niches. Of the 1.2 million net new jobs in Canada from 1978 to 1985, as many as 81 per cent came from businesses with fewer than 20 employees and 59 per cent from those with fewer than five employees. Job creation is in many respects based on the creation of new firms, and some estimates suggest that

more than 50 per cent of the new jobs in the next five years will come from firms yet to be formed.

The success of new, small businesses will depend to a large degree on their ability to take advantage of new technologies. In recent international comparisons Canadian small business stands out for its alertness in introducing new technologies. Canada still needs to assist small business, however, through new creative mechanisms for technology transfer that are sensitive to the problems and opportunities faced by each small-business sector.

One initiative that warrants support is a revision of the Small Business Loans Act to guarantee loans that support high-risk transfers of technology that might otherwise not proceed. Such a new policy should also relieve firms of at least some of the burden of funding collateral, which otherwise limits the use of their own funds for operating capital. Loan guarantees have been used more in countries such as Japan and West Germany than in Canada.

Strategic partnerships

Small technology-based firms are often good at innovation but less able to capture the ensuing wealth. Whether they profit from their innovations depends in part on the legal mechanisms, such as patents and copyrights, that protect—or should protect—their technology, and whether they can keep imitators and followers at bay. Where their technology is reasonably protected there are often advantages in contracts with other firms, usually much larger ones that have complementary assets such as marketing, specialized manufacturing, or after-sales support. Such arm's-length contracting is known as strategic partnering. The need for strategic partnering is more acute because of the undercapitalization so common among small technology-based firms. Some of these partnerships involve an investment by the larger firm to provide the smaller one with equity capital for R&D or to support collaborative R&D.

Adequate capitalization is especially necessary for small technology firms in the critical transition from start-up to the second stage. That is when R&D expands and many new jobs are created, yet it is a phase in which the costs of investigating and monitoring deter venture capitalists and other financial institutions. Typically the technical entrepreneur is left haphazardly to seek and depend on investors in the informal

risk-capital market. Those investors are hard to find, especially outside a few leading cities.

The gap between the seed- and venture-capital financing phases is more debilitating in Canada than in the United States. There, strategic partnering has developed more to bridge the gap. It is an approach well suited to the world of advanced technology; it leaves control with the start-up company but involves the sale of rights, such as marketing rights, by the start-up to an established, generally large firm. The large firm is usually technology-driven and needs diversification or additions to its product line suited to its downstream capacity. For the large firm, such partnering can be more effective than acquisition. For the small firm, it can be a potent and profitable way to develop products and break into international markets.

Strategic partnering is increasing in Canada, but it is still very limited. Often partnering is between Canadian start-ups and foreign firms. The lack of domestic partners is probably in part because in many foreign-owned Canadian subsidiaries, head offices outside the country make such decisions. That may diminish the ability or incentive of subsidiaries to search for opportunities, especially subsidiaries that lack technical expertise in product development.

Increasing technological innovation by small firms in Canada may not in itself create wealth or increase international competitiveness, if the innovations are not readily protected from imitation. Even when they are protected, the innovators still need to obtain funds for complementary assets or find a strategic partner. In this light, it is particularly important in small and medium-sized countries for public policy to focus not only on R&D, but also on complementary assets and the supportive infrastructure. Otherwise, much of the profit from innovation will flow to foreign imitators and other competitors.

ISTC, regions, and provinces

The formation of Industry, Science, and Technology Canada and the decentralization of federal regional development to the Atlantic Canada Opportunities Agency and the Western Diversification Office, plus the increasing provincial and municipal initiatives in science and technology strategy, are all encouraging. But they do raise the possibility of duplication and excessive fragmentation in S&T investment. If all these efforts are to be efficient, effective, and responsive to local opportunities and needs, there must be close cooperation between them.

Each region and province should ensure it has a suitable consultative process for developing its own technological identity and priorities. Part of the process should be designed to minimize any ill effects of interregional competition and dilution of S&T resources. And ISTC, while fulfilling its national responsibilities (including its regional responsibilities for Ontario and Quebec), must not ignore its role in promoting S&T opportunities in Atlantic and Western Canada. The federal government should ensure that a coordinating committee of the federal ministers responsible for S&T investment (through ISTC and its sister agencies in regional development) addresses the task of avoiding duplication and unproductive interregional competition in S&T investment and avoiding jurisdictional disputes.

Intellectual property

The variety of recent trends in Canadian and foreign technology strategies contributes to making intellectual-property management more demanding a job within firms and more challenging for policymakers. As Canada moves toward building a more knowledge-intensive economy, more of its producers, particularly high-technology firms, become vulnerable to the intellectual-property laws and enforcement measures of competing countries. The protection of intellectual property is important for many of our medium- and high-technology exporters. And many of our imports come from countries notorious for their intellectual-property violations.

Canadian policymakers and Canadian firms must develop the expertise to address these increasingly important intellectual-property issues. National policy must be refined, based on knowledge of emerging industry attitudes and practices; it must balance the interests of importers and consumers, who want continued access to inexpensive foreign goods, with those of Canadian producers, who require protection from unfair competition.

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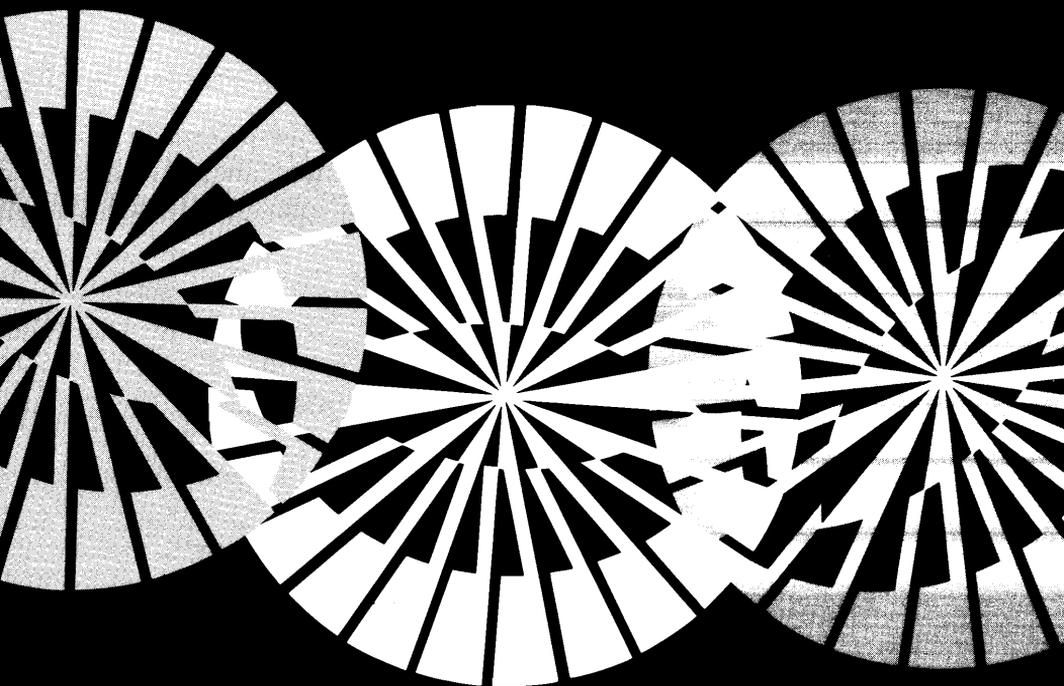
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- analyse science and technology policy issues;
- recommend policy directions to government;
- alert Canadians to the impact of science and technology on their lives;
- stimulate discussion of science and technology policy among governments, industry and academic institutions.



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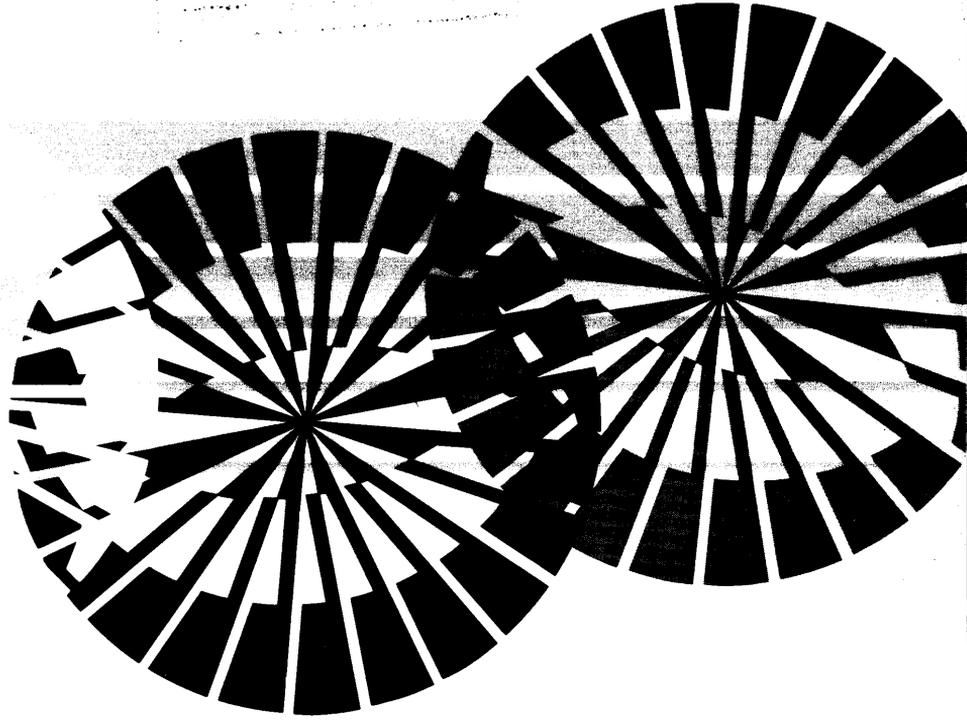
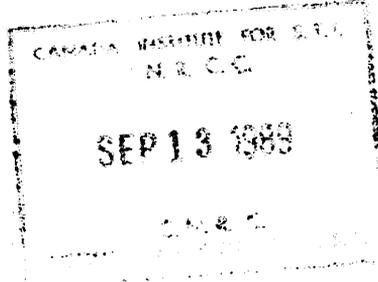
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Summary

Summary of Background Study 55

Not a Long Shot

Canadian Industrial Science and
Technology Policy

Guy P. Steed



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Not a Long Shot

Canadian Industrial Science and Technology Policy

Guy P. Steed

July 1989

ANALYZED

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As the next century approaches, a golden era of science and technology is contributing to a historic economic transition. And if Canadians are to emerge among the rich and the strong, their science and technology policy must be honed to be more of a sure bet than a long shot.

This is the message of *Not a Long Shot: Canadian Industrial Science and Technology Policy*, the Science Council of Canada's Background Study 55, written by Guy Steed.

Dr Steed outlines the fundamental changes that are being wrought in the world economy as a result of advances in science and technology. These changes profoundly influence the international competitiveness of Canadian industry and, consequently, the economic wellbeing of all Canadians. His study reviews the S&T policies of industries and governments in Canada and suggests changes that would help this country, through economic renewal, to maintain its standing as one of the world's advanced industrial nations.

The changing world economy

Dr Steed notes a number of new trends in the world economy. For instance, increases in the value of industrial production no longer imply matching increases in the use of primary products or of labour. And it is more the movement of capital that drives the world economy than the movement of goods and services.

Canada's S&T policies, he says, must take account of the decline of the former superpowers, the United States and Soviet Union, and the rise of Japan and other Asian and Pacific economic powers. Many of these countries are expected to increase their per-capita incomes four times as fast as Western industrialized countries.

Dr Steed also considers the impact of new information technologies, biotechnologies, and advanced materials. These are spawning entirely new industries (with lower requirements for land, labour, capital, and natural resources than older industries) and are transforming the way industry is organized. Although manufacturing output holds about the same share of gross domestic product that it has in the past, this output requires less labour. However, the loss in blue-collar jobs has largely been outweighed by an increase in service-sector jobs and the growth of knowledge-intensive industries.

The information technologies, according to the study, are leading to a shift toward flexibility, novelty, and quality. The emphasis on mass production of standard goods by huge corporations is diminishing, and small firms have become the dominant source of new jobs in advanced countries. There has been a growth of information-based service industries, many serving other businesses, and increasing global integration of production, services, and markets. In this dynamic environment, most developed countries face a deep-seated problem of international competitiveness. The need in Canada is for S&T policies that will keep our industry competitive.

In world markets, high-wage countries increasingly are competing by improving production efficiency and offering new, technically sophisticated products, for which an educated, technologically oriented workforce is needed. Technological innovation is seen as an important catalyst of wealth creation and industrial change, and proprietary technological knowledge is driving the capitalist engine.

However, Dr Steed warns that scientific leadership does not in itself assure economic benefits. As recent British experience shows, it must be matched with managerial and engineering skills. "Innovative firms often fail even when imitative firms succeed."

Marrying S&T with industry

Innovating nations must improve their protection of intellectual property. Where this is not feasible, the nation must be able to capture the spillover benefits from innovation. A major issue, therefore, is how best to couple the S&T and industrial systems, so that scientific advances can quickly be translated into new or improved goods and services.

Japan, Dr Steed points out, has proved the most successful nation in developing and embracing new technologies. In that country, companies integrate research and development with engineering design, procurement, production, and marketing. There are workers with skills and attitudes conducive to rapid technological change and high-quality output. The large conglomerates are flexible enough to direct their capital and human resources to the best channels. And long-term government policy enables public and private sectors to be ready for future technological advances.

In all advanced countries science and technology have become more industry-oriented. Industrial research and development grew during the 1970s, and often business has supplanted government as the chief source of R&D funds. Doing basic research not only leads to new developments, it also helps the firms that do it to understand processes and products, keeps them informed of scientific advances, and maintains scientific and technological standards. Moreover, the S&T system has become internationalized — multinational firms have laboratories in several countries, and firms carry out joint ventures with firms and governments in other countries. Several Japanese and European firms have commissioned research in American laboratories, and large companies frequently invest in small foreign firms to gain access to their technological know-how.

Thus there is a transnational flow of technology. Most countries, other than the United States and Japan, generate only a 15th to a 20th of the technology they use. Thus technology diffusion is complementary to technology development. Countries strive both to improve their speed of adoption of foreign-generated technology and to improve the transfer of technology to domestic industry from their own government and university laboratories.

The S&T policies used by the governments of advanced countries vary. The United States and France, for instance, depend heavily on defence procurement as a tool for generating new technologies. The policies of other countries, such as West Germany, Switzerland, Austria, and Sweden, are oriented more toward diffusion of technology. From the experience of many advanced countries, Dr Steed's study draws a series of lessons for technology development, although he warns that what is appropriate in one country may not be so in another. Particularly, he stresses that large countries can pursue development in many ways, whereas smaller ones such as Canada have to seek niches — to choose the kinds of technology in which they can best succeed.

How well is Canada doing?

Over the past 6 years the Canadian economy has done well on a number of measures including economic growth, gross national product per capita, and job creation. But on other measures, such as rate of unemployment, inflation, and overall productivity growth, performance has been lacklustre. Of the 12 most industrially developed nations, Canada's manufacturing sector recorded the slowest productivity growth between 1977 and 1986. And although Canada created more net new jobs in 1986-88 than the 12 nations of the European Economic Community combined in the past 15 years, these were mostly in the low-productivity service sector. Furthermore, Atlantic and Western Canada have not shared in the improving economic picture.

Canada relies heavily on exports, most of which are raw and semiprocessed products. These are vulnerable to protectionism in other countries and to new technologies that can replace these materials. Thus there is a need for new industrial strength through innovation. "The status quo is not good enough," the background study states flatly. Yet, with manufacturing productivity 30 per cent below that of our major trading partners and a feebler R&D base than theirs, catching up will be tough.

Since 1970 Canada has, in fact, been shifting out of low-technology industries into medium-technology ones — transport equipment, chemicals, rubber and plastics, non-ferrous metals, and some types of machinery. In high-technology products, Canada had a trade deficit in 1987 estimated at \$7 billion according to one definition of "high technology" and at \$13 billion according to a broader definition.

Canada, says Dr Steed, nestles in the middle of the pack of industrialized countries when ranked on ability to innovate. Available evidence — on robot technology, automated inspection and quality control, automated materials handling, and micro-electronics in processing — suggests a gap in adoption levels between Canada and other advanced countries. But investing in modern equipment is not in itself enough. It is critical to use it effectively. Even where new technology is introduced, it may not be fully exploited because of inadequately trained workers and poor integration with the whole production system.

The study records that Canada's spending on research and development is about 1.4 per cent of gross domestic product. This compares to 2.9 per cent in the United States and 2.0 to 2.6 per cent in the Netherlands, France, Britain, Sweden, Japan, and West Germany. Overall spending on R&D by the Canadian government is reasonably comparable to that of other governments; however, relatively little of it goes into support of industrial R&D, partly because spending by Canadian industry on research and development is inadequate. In Canada, 25 firms perform more than half of all the industrial R&D (although only three spend more than \$100 million a year on it). Of the \$2.7 billion spent on industrial R&D in 1985, \$1.6 billion was spent in Ontario and \$0.6 billion in Quebec. The telecommunications industry spent 13.4 per cent of sales on R&D, followed by aircraft (10.1 per cent), other electronic equipment (7.3 per cent), electronic components (4.9 per cent), and drugs and medicines (4.0 per cent).

Dr Steed notes that the results of research and development are used not only by firms that perform the R&D, but also by imitators. However, to reap the most benefit from such spillovers, a firm must have an R&D operation of its own; acquiring and developing technology are complementary activities. This also implies that Canada cannot fully compensate for lack of industrial R&D by simply purchasing and importing more technology.

Government support for S&T

In 1987 the prime minister said the fundamental challenge is to use science and technology to strengthen Canada's competitive position. The private sector, he concluded, must perform a greater share of the national S&T effort. Canadian governments announced in that year policies to enhance the performance and diffusion of science and technology, with the new Council of S&T Ministers to oversee them. The prime minister himself chairs the National Advisory Board on Science and Technology, which also includes the ministers of finance, industry, and science.

Federal S&T policy is now implemented by the powerful new department, Industry, Science and Technology Canada. It aims at industrial innovation and technology transfer, with an emphasis on small business.

There is support for generic research and R&D partnerships, and there is emphasis on facilities and personnel training. The government proposes to encourage private investment in S&T through tax incentives, new competition laws, better patent protection, and liberalized trade.

Numerous government initiatives have been announced — \$685 million over five years to match private-sector funding of university research and \$824 million over five years to the Canadian space program, for instance. Dr Steed suggests much of it was smarter spending of money already planned, but in early 1988 an additional \$1.3 billion over five years was announced. Bearing in mind, however, that industry lost some support for R&D through recent tax reform, Dr Steed suggests Canada's public support for industrial R&D remains meagre in comparison to that of other countries.

The study examines the implications of tax reform, free trade, and regional development in promoting science and technology. It concludes that the government has chosen, by eliminating some tax shelters, to give greater weight to fairness than to enhancing competitiveness and has dampened the climate for innovative new companies.

One intent of the free trade agreement with the United States, says the study, was to improve productivity, reduce production costs, and enhance Canadian competitiveness. By 1989 most high-technology products will face no tariff barriers between Canada and the United States. However, the agreement will likely increase technology transfer by encouraging investment. It is largely silent over patent protection; also, the question of whether government support of R&D is an allowable, non-countervailable subsidy remains undefined.

Dr Steed suggests that preoccupation with the agreement should not distract Canada from either the "enormous potential benefit" from directing S&T resources toward stronger ties with Japan or the opportunities available after 1992 when the European Economic Community phases out all internal trade barriers.

In his review of science and technology in regional development, Dr Steed makes the point that economic forces have largely concentrated research and development in Toronto, Ottawa, and Montreal and that to accommodate regional demands for R&D facilities involves

a trade-off with efficiency. A national policy has the problem of how to support excellence in the face of politicization and regional pull. There are, he says, no simple, quick fixes.

Looking ahead

What, then, are the issues for the 1990s? Dr Steed cites evidence that detailed information on a new commercial product or process generally leaks out within a year. Technology pirating has grown dramatically in recent years; counterfeiting of computer software costs several thousand Canadian jobs annually. So protection of technological knowledge is seen as being, in two ways, an emerging problem. First, other countries are becoming more anxious to withhold such knowledge so they can use it for their own advantage. Second, Canada needs better mechanisms not only to protect her own technological knowledge, but also to assure other countries that if they do transfer technology to Canada it will be protected.

The globalization of trade and investment has meant that all countries are facing a foreign investment problem, but this is acute in Canada. Other countries that have seen their rates of foreign investment increase rapidly, even to levels far below those in Canada, have been concerned and have often taken action.

Trade in professional services is becoming an issue in the information economy. Canada has strengths, notably in consulting engineering, but barriers to trade through regulation or unfair subsidies are a concern that will persist.

Emerging technologies may further heighten environmental concerns. Dr Steed points out that a commitment in Canada to cleaning up water resources could lead to opportunities for an internationally competitive industry based on our first-class water science.

His broad argument is that for Canada's future prosperity, manufacturing capability matters, technology policy matters, and geography matters. Based on the premise of a substantial need for industry self-help as well as a supportive and partnership role for government, he proposes a number of ways to enhance Canada's S&T-based industrial renewal:

- **More supportive government financial policies:** Although tax support is good in Canada, non-tax support is not as good as in other countries.
- **Self-help by industry:** Technological staff need to be in higher and better-paid ranks within management, and boards must have some directors with knowledge of technological affairs. Thorough investigation of markets, especially foreign ones, should precede research, development, and design. Canadian offices in foreign countries should help domestic firms with information on markets and financing, and foreign study and language training should be available to engineers.
- **World-class companies:** Canada should strive to develop dynamic, world-class, large companies as well as small companies, many of which could grow and operate multinationally. Small firms also could find niches by becoming suppliers to larger firms.
- **Sectoral innovation:** Consultation between industry associations and government should define the kinds of S&T action that would help innovation. A start might be made with resource-based industries.
- **Selectivity:** Limited resources are now spread too thinly; Canada's research efforts have to be more selective. Better input from industry associations would aid this process.
- **Major programs:** The Canadian government could allocate funds for research in certain programs that would have the effect of developing technological expertise. Two such programs might be in environmental technologies and in engineering and industrial design.

The specific recommendations drawn from these six key priorities for action are contained in the Science Council of Canada statement of October 1988, *Gearing Up for Global Markets: From Industry Challenge to Industry Commitment*. Dr Steed also proposes six other ways, of lesser importance, of taking useful action:

- **Cooperative research:** Research is becoming too expensive for many small firms. The answer, in part, is research pools and research with broad applications, supported by government.

- **University-industry cooperation:** University research for a corporation is financially attractive. There need to be better links between universities and industry. Personnel exchanges and new attitudes are ways to achieve this.
- **New, small, technology-based firms:** Governments now have policies to encourage small entrepreneurs. More can be done. University training for technological entrepreneurs would help. So would better sources of venture capital and help with technology transfers.
- **Strategic partnerships:** These are partnerships between small, innovative firms and larger corporations with access to capital and markets.
- **Regional policies:** Departments and agencies of the federal, provincial, and regional governments are working to stimulate S&T-based enterprises throughout the country. Coordination is needed.
- **Protection of intellectual property:** This is increasingly difficult, given the internationalization of S&T and the violations of intellectual property in many countries. Canadian business must develop the expertise to address this issue.

Copies of the full **background study** (146 pages)

Not a Long Shot: Canadian Industrial Science and Technology Policy
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