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Technology and the Canadian Forest-Product Industries A Policy Perspective

Roger Hayter



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Foreword

Technological innovation and its contribution to productivity advances have become central policy issues in all advanced industrial countries during the 1980s. In Canada federal and provincial governments are turning to science and technology to fuel the economic renewal of Canada's leading resource industries.

As part of its emerging science and technologies program, the Science Council of Canada commissioned this background study of technological innovation in Canada's forest-product industries. The study reviews the stages of technological innovation, including generation of forest-product technology and technology transfer; the context and state of R&D by and for the forest-product industries; the roles of forest-product firms, equipment suppliers, government laboratories, and cooperative laboratories; and the nature of modernization strategies. It provides background to a Science Council statement that details how the international competitiveness of these industries can be enhanced.

The study is based on substantial consultation with senior executives in the forest-product industries, and industry leaders who had the opportunity to review an earlier draft agreed with its conclusions. As one senior executive commented, "A lot of people in the industry should read it." The Science Council is pleased to make the report available to a wider audience.

Guy P.F. Steed Associate Director of Research Science Council of Canada

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This study would not have been possible without the willing cooperation and valuable information provided by numerous business executives and federal and provincial officials. Their help is gratefully appreciated. At the Science Council, Guy Steed, associate director of research, has been a source of moral support and constructive criticism.

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Chapter 1

The Technological Challenge

Over the past decade Canada's share of international forest-product trade has seriously diminished. It has been a difficult period globally for the forest industries, but their problems in Canada are particularly severe. Traditional bulk commodities, such as softwood lumber, in which Canada remains the major world exporter and an efficient producer, are vulnerable to overcapacity cycles, demand changes, exchange rate fluctuations, and protectionism in export markets. Higher value wood and paper products are less vulnerable, but here Canada's performance has been weak. In a country in which the forestproduct industries rank collectively as the most significant manufacturing sector, any relative decline in those industries is alarming. But the decline need not continue.

This background study argues that the forest-product industries of Canada face a fundamental challenge: to change themselves from producers of a few bulk commodities whose profitability depends on cost minimization into diversified and flexible manufacturers that serve a wide range of geographical markets and whose profits stem from value maximization. The challenge is formidable.

During the postwar boom the growth of the forest-product industries was predicated on access to high-quality, cheap timber and the massive demands of the industrial powers, especially the United States, for lumber, pulp, and newsprint. As marginal suppliers of standardized bulk commodities, Canada's industries rested comfortably on a narrow range of maturing technologies.

Now the situation has changed. In particular, Canada's great advantage of access to plentiful high-quality, long fibre softwood has been reduced by its exploitation, by the establishment of softwood plantations in other countries, by technologies that have economically extended the use of hardwoods in wood-processing and pulp and paper making, and by increased self-sufficiency in Canada's major markets. In addition, as markets for forest-products have become more quality conscious and differentiated, market growth in bulk lumber, pulp, and newsprint has levelled off or even declined. Unfortunately, as the Science Council recently stated:

Although the Canadian industry may have anticipated these changes, it has not responded effectively. Pulp producers have not adapted to the shift from softwood pulp to hardwood pulp. Even though specialty papers are one of the fastest growing segments of Canadian production, newsprint producers have not adapted sufficiently rapidly to the increasing demand for higher quality papers such as those used in advertising inserts.¹

Similar comments can be made regarding wood-processing. The failure of the Canadian lumber industry to meet the needs of the massive Japanese housing-construction market is also a result of the rigidity of Canadian thinking.²

The forest-product industries have not fully accepted that the era of extensive growth, based on the construction of new mills in fresh timber supply areas, is over. They still have only limited knowledge about growing and using second growth timber, which is qualitatively different from that first harvested. In addition, because they are "technologically unsophisticated" they have not been able to move quickly into fast-growing markets for value-added products.³ The challenges that they face are both to introduce appropriate forest management practices and to equip themselves technologically to serve these new, often far-flung, markets.

To meet these challenges the Canadian forest-product industries must commit themselves to innovation and technological excellence by investing more money in in-house R&D, by modernizing existing facilities and investing their capital in innovative new equipment and facilities, and through aggressive marketing strategies.

Scope and Objectives of this Study

Policies to encourage technological innovation in the Canadian forestproduct industries must be based on an understanding of what technological innovation is and of the strengths and weaknesses of the existing network of private and public laboratories — the R&D system. A few studies have described the size and scope of R&D in the Canadian forest-product industries in the 1970s and explored the diffusion and impact on productivity of specific items of equipment. In mandate and emphasis this study resembles reports by Smith and Lessard and by Solandt, both of which defined and assessed forestproduct R&D in Canada and offered policy suggestions⁴; however, it devotes more attention to the role of in-house R&D, to "technological liaisons" or information pathways within the R&D system, and to case studies of innovation. Smith and Lessard and Solandt paid more attention to university and government R&D.⁵

This study of technological innovation (including R&D) in Canada's forest-product industry seeks to

1. determine the nature and scope of current R&D;

- 2. outline the directions of technological change over the past 15 years and comment on future directions;
- 3. identify the roles of various Canadian-based organizations in technological innovation;
- 4. identify the strengths and weaknesses of the R&D system;
- 5. assess some recent cases of modernization and describe the search and evaluation procedures used in selecting technology and technology suppliers;
- 6. recommend government policies to improve technological capability;
- 7. recommend corporate policies regarding the innovation (including R&D) and manufacture of forest-product technology.

Research Design

This study is based on substantial consultation with industry leaders. It draws on four sets of interviews; two of which involved questionnaires. For the first survey the author contacted R&D managers of forest-product firms (or a vice-president or director) and arranged a person-to-person interview; where this was not possible, the questionnaire was mailed. Of the 12 executives contacted eight granted interviews and two replied by mail.⁶ The firms with the largest R&D efforts — MacMillan Bloedel, Abitibi-Price, Canadian International Paper, and Domtar — all participated. The author also interviewed senior executives at three U.S.-based laboratories to obtain some comparative insights.

For the second questionnaire survey the author contacted managers of R&D or marketing at approximately 130 equipment suppliers; 37 managers completed questionnaires, including 16 at face-to-face interviews. The firms contacted manufacture a range of goods including logging equipment, wood-processing machinery, pulping and paper-making machinery, and electronic equipment. The sample of 37 includes most of the leading R&D performers. In addition representatives of two chemical companies, one of which has a significant R&D effort in Canada, were interviewed.

Both surveys were concerned with identifying the size and scope of R&D operations, the nature of technological liaisons, and the likely future direction of R&D.

A third set of interviews was arranged with senior managers who had recently been involved in a decision to modernize either a sawmill or a pulp and paper mill. The interviews provided general insights into why they modernized and how they went about it, including how they went about selecting new equipment. Finally, the author interviewed senior managers in government (for example, the Ontario Research Foundation) and other institutions involved in forestry-related R&D. The other institutions were the Forest Engineering Research Institute of Canada (Feric), Forintek, and the Pulp and Paper Research Institute of Canada (Paprican). Interviews were open-ended and focused on the size, scope, and evolution of R&D efforts and the nature of technological liaisons.

Information was also obtained from the most important trade magazines.

The Canadian Forest-Product Industries

Significance

The forest-product industries, conventionally defined to include logging activities, wood-processing, and paper and allied industries, are of critical importance to the Canadian economy. By the early 1980s these industries directly employed about 300 000 people and indirectly supported many more in linked activities in the manufacturing sector, notably the machinery, metal fabricating, transportation, and chemical industries; the construction sector; the service sector, notably engineering consultants and a variety of business services; and the government sector. Locally, the forest-product industries provide the economic base for several hundred one-industry communities throughout Canada. Regionally, they are the most significant manufacturing activity in the Atlantic Provinces, Quebec, and British Columbia, and they are also important to the economies of Ontario and the Prairie Provinces.

The forest-product industries, excluding the linked activities, generate shipments whose value consistently exceeds that of mining, fishing, and agricultural exports combined. Even in recent years the forest-product industries have accounted for almost 20 per cent of Canada's total merchandise trade. Newsprint, pulp, and lumber dominate Canada's forest-product output and export levels (Table 1.1). In 1981, for example, these products ranked third, fifth, and seventh respectively in terms of Canada's gross export revenues, and in recent years Canada has accounted for over 60 per cent of world newsprint exports and over 70 per cent of world kraft pulp exports. In fact, Canada supplies one-third of the world's pulp and paper exports and is the world's largest exporter of these commodities. Canada's forestproduct industries are therefore strongly export-oriented. Their markets have been for some time concentrated in the United States (Table 1.2). The most notable trend, especially in the case of pulp, is a modest shift toward European and Asian markets.

	19	71	1981		
	Production	% Export	Production	% Export	
Newsprint ^a	7764	85.1	8 981	89.1	
Paperboarda	1673	21.8	2 343	21.7	
Other paper ^a	1 572	37.0	2 301	50.5	
Chemical pulpa	1 001	51.9	12 362	53.2	
Lumber ^b	30 055	66.9	39877	68.4	
Softwood plywood ^c	195	17.3	107	18.8	

Table 1.1: Production and Export Levels of the Principal Canadian Forest-Product Commodities, 1971 and 1981

Source: Statistics Canada, *Pulp and Paper Mills* (Ottawa: Minister of Supply and Services, 1971 and 1981), cat. no. 36-204.

^a Thousand tonnes.

^b Thousand cubic metres.

^c Million square metres.

Table 1.2: Percentage Canadian Forest-Product Exports by Product and Destination, and Total Value (Millions of Dollars) by Product, 1951 and 1978

	1951			1978		
	Lumber	Pulp	Newsprint	Lumber	Pulp	Newsprint
U.S.	63.0	75.8	92.7	82.0	54.0	81.4
Europe	25.8	7.4	1.9	8.0	28.7	8.1
Australia	12.7	5.0	5.0	8.7	12.7	4.5
Other	4.1	11.8	4.6	1.3	4.6	5.6
Total value	\$312	\$365	\$536	\$3 230	\$2180	\$3111

Source: R. Hayter, "The evolution and structure of the Canadian forest product sector: an assessment of the role of foreign ownership and control," *Fennia*, 163 (1985): 441.

Ownership and Control

Historically, the Canadian forest-product industries have attracted a high level of foreign investment. By the late 1970s, for example, when foreign ownership was close to its peak, foreign control varied from 29.9 per cent (lumber industry) to 44.1 per cent (pulp and paper), if control is defined as at least 50 per cent ownership (Table 1.3). If foreign control is calculated on the basis of foreign residents having at least 25 per cent ownership, then the level of foreign control increases by 5-10 per cent in each of the principal commodities. As would be expected, foreign investment parallels export trade: American firms dominate and European and Japanese firms are important? A few Canadian firms have expanded internationally, principally in the

	Capacitya	Percentage ^b Foreign F	Controlled by Firms with
		50% Equity	25% Equity
Soft lumber	94 763°	29.9	38.5
Soft plywood	297d	41.8	48.5
Pulp and paper	80 717e	44.1	51.4
Newsprint	30 043e	40.2	45.8

Table 1.3: Degree of Foreign Control of the Canadian Forest-Product Industries, 1979

^a Capacity data were derived by summing individual mill capacities as recorded in the *Directory of Forest Product Industries* and Post's *Pulp and Paper Directory.*

^b Statistics Canada, *Inter-corporate Ownership* (Ottawa: Minister of Supply and Services), cat. no. 61-517, provided precise information on the degree of foreign ownership of individual firms in 1975 and *The Canadian Forest Industries* was consulted as a check on subsequent ownership changes. See R. Hayter, "The evolution and structure of the Canadian forest-product sector: an assessment of the role of foreign ownership and control," *Fennia*, 163 (1985): 439-50.

^c Million cubic metres.

^d Million square metres.

e Estimated tonnes.

United States and Europe. Indeed, the Canadian forest-product industries have been increasingly dominated by large horizontally and vertically integrated firms. In 1970, for example, seven firms manufactured 54 per cent of the newsprint, 20 per cent of the lumber, 34 per cent of the plywood, more than half of the converted paper products, and substantial tonnages of the market pulp and paperboard produced in Canada.⁸

For Canadian forest-product firms the 1970s and 1980s have been marked by considerable instability. The energy crisis of the early 1970s and rapidly rising rates of inflation have been accompanied by increasingly severe recessions in 1970–71, 1975–76, and 1981–82 and by changes in the organization of the global economy. The 1981–82 recession resulted in financial losses, bankruptcies, plant closures, and high debt–equity ratios and stimulated attempts by firms to reduce costs and to restructure operations. As part of their restructuring, several foreign firms sold their Canadian operations, in most cases to Canadian firms, especially conglomerates. As a result, increased Canadian ownership of forest-product industries has been associated with an enhanced role for conglomerates. These trends have important implications for innovation policy.

A Sunset Sector?

Over the past decade Canada's resource industries have been increasingly referred to as a "sunset sector" whose contribution to the economy must necessarily wane. The recessionary conditions of the 1980s have been seen as a watershed marking the shift from an "old" to a "new" economy and from "sunset" to "sunrise" sectors.⁹ The distinction between sunrise (youthful) and sunset (mature) industries rests on an interpretation of industrial evolution in which the various stages in an industry's life cycle such as birth, youth, maturity, old age, and death are distinguished primarily by technological characteristics: as an industry matures it is necessarily progressively less influenced by technology-based change from within the industry.¹⁰

This interpretation is based largely on experience in secondary manufacturing, and it suggests that as industries evolve the rate of major innovation falls and they turn from new product development to process optimization and cost reduction (Figure 1.1). It postulates a shift from entrepreneurial organizations, small-scale plants, flexible production processes, and diverse and changing product-mixes to efficient, large, capital-intensive plants specializing in a narrow range of products.¹¹

The argument that the Canadian forest-product industries are in a sunset sector rests upon this model of an industry's life cycle. Its adherents point out that the investment strategies of forest-product firms are oriented toward the rationalization of facilities and that technological change in the sector is primarily incremental, processoriented, and labour-saving. The forest-product industries compete on the basis of costs. And Canada is at an increasing disadvantage with respect to the two principal factors of production, labour and timber. Canada's forest resources are now less attractive in terms of availability and quality than those in other countries.

Despite their problems, the forest-product industries are still important to the Canadian economy. They should not be dismissed as a sunset sector, mature in technology, and on an inevitable path of decline.

Certainly the Canadian forest-product industries are experiencing significant changes and they will not provide the same kind of platform for growth as they did in the past; yet their decline is by no means inevitable. For one thing, long-term trends in production and sales simply do not conform to conventional life-cycle notions.¹² For example, the birth and rapid growth of the Canadian lumber industry until 1911 was followed by almost 40 years of "no-growth." Then the industry expanded impressively over the next 30 years. Perhaps the levelling off in the rate of growth of lumber production and in other forest-product commodities during the 1970s is not necessarily a death rattle.



Source: After Utterback and Abernathy, 1978.

Future prospects for individual products are varied, and neither market opportunities nor timber supply considerations need arrest the development of the Canadian forest-product industries. The Food and Agriculture Organization of the United Nations, for example, predicted an increase in global demand for forest-products until at least the end of the century and identified Canada as a major source of supply.¹³ Other knowledgeable observers have also recently concluded that global forest-product markets will grow.¹⁴ In fact, Canada's pulp and paper industry, which produced 21.6 million tonnes of pulp, paper, and paperboard in 1985, is seen to be a 30-million-tonne industry by 1995.¹⁵ Some would debate the view that the main constraint to the viability of existing forest-based industries in Canada is timber supply.¹⁶ But even if this view is accurate, the problem can be resolved by appropriate forest management action within Canada.¹⁷

The success of the Canadian forest-product industries in changing circumstances will depend upon their innovativeness. The conventional theory of how industries age considerably underestimates the technological dynamism of the forest-product industries. The present period of restructuring can be seen as an opportunity for renewal and adaptation rather than simply a cost and capacity-cutting exercise. Indeed, the rate of major innovation has not declined smoothly over time. There is now substantial empirical evidence from many mature industries (for example, auto, steel, textile, and cutlery manufacture) for periodic clusters of major innovation activity and that, at any given time, a wide variety of technology options have been available and chosen.¹⁸ Within the forest-product industries, the past 20 years have seen increasingly rapid technological change, including the application of microelectronics, and increasingly complex technological choices.

Technological Change in the Forest-Product Industries

Technology is changing at an ever increasing rate, from axe to crosscut saw in 100 years, crosscut saw to bow saw in 45 years, bow saw to chain saw in 30 years and currently chain saws are being displaced by machines with shears or circular-saw felling heads, each period decreasing by about one-third.¹⁹

During the Industrial Revolution, wood-based pulp and paper manufacturing became viable with the introduction of the Fourdrinier paper machine and groundwood and chemical pulping processes; other new technologies at that time were large-scale band and gang sawmilling technologies and the cross-cut saw. The underlying technological principles of these innovations did not change for some time. Incremental technological changes increased the scale of operations and labour productivity. For example, between the 1890s and 1930 the speed and width of the Fourdrinier machine increased fourfold.²⁰ An American study noted that despite the lack of major innovations between 1919 and 1940, labour productivity in the pulp and paper industry increased by over 4 per cent per year.²¹ The study shows how substantial the cumulative impact of incremental technological changes can be on productivity.²² Since 1945 the pace of technological change in the forest-product industries and in silviculture throughout the globe has quickened. Forest management techniques such as site preparation, regeneration, thinnings, and genetics have progressed considerably over the past three decades. In wood harvesting, Silversides describes a variety of increasingly expensive locally developed and imported machines designed to delimb, fell, bunch, and skid timber.²³ He reveals that the life expectancies of new innovations for forest-harvesting operations have declined dramatically over the past 100 years.

Since 1950 new processing technology in the lumber and plywood industries has widened manufacturing capability and enhanced labour productivity. For example, prior to 1970, in Canada, Schwindt noted 13 "major" and 11 "less significant" innovations in these two industries.24 Since 1970 new major processing technologies have included the "best operating" method of cutting; log scanning; saw, dry, and rip technology for hardwoods; and widespread applications of microelectronics. The latter trend has been massively laboursaving. There have also been significant new wood products within the past 40 years. During the 1950s the variety of plywood products expanded. In addition, the industry developed laminated beams, hardboard, and particleboard in the late 1950s and 1960s and then introduced wood trusses, laminated veneer lumber, plywood webbed I-beams, waferboard, hardboard webbed I-beams, oriented strandboard and, most recently, composite lumber and hardwood lumber. Development of these products reflected the changing availability of raw materials and important changes in the use of wood in house construction.²⁵ Indeed, sawmills have been undergoing a "technological revolution."

In the paper and allied industries the pace of technological change has been equally impressive. Schwindt, for example, identified 21 "major" and 14 "less significant" innovations between 1950 and 1970.²⁶ Since 1970 there have been a number of notable developments in bleaching, pulping, and paper-making: for example, there has been rapid development of high-yield processes such as thermomechanical pulping (TMP), chemimechanical pulping (CMP), chemithermomechanical pulping (CTMP), and anthraquinone (AQ) kraft pulping. To reduce pollution and to offset increasing wood fibre costs, the new high yield pulps have wood fibre recovery rates in excess of 90 per cent; in comparison, the recovery rates associated with the established kraft and sulphite chemical pulps range from 47 per cent to 53 per cent. The new pulps are clean and bright, and capital costs and economies-ofscale are much lower for a new bleached CTMP mill than for a new bleached kraft pulp mill.²⁷ The most notable technological development in the paper and allied industries, however, is that within the past decade the traditional Fourdrinier paper-making machine has become obsolete with the development of "twin wire" or "twin-forming" technology. Twin-forming technology was first introduced in Canada at Trois Rivières in 1968 and has spread rapidly since 1976. It has replaced the Fourdrinier because it makes a better two-sided paper, significantly reduces linting, and permits the use of higher-yield pulps. Twinforming technology was pioneered in Canada by Paprican. More recently the so-called "top former" has been developed as a cheaper alternative to twin-forming technology. In association with the development of twin and top formers there have been substantial changes in other elements of paper-making such as forming fabrics, felts, winding technology, and press drying.

The paper machine has also changed dramatically as a result of computerization. Minicomputers were first applied to paper-making processes in the late 1960s and the success of these early systems with respect to, for example, improved performance, better quality, and better use of raw materials by paper machines, led to further rapid development. By 1976 the microprocessor had been used for small-scale controlled instrumentation and began to replace control by electronic analogue, which had replaced pneumatic control methods. As an alternative to the minicomputer and miniprocessor, programmable logic controllers (PLCs) were also introduced to control specific tasks during the 1970s.

Parallel with these developments have been substantial improvements in the design of sensors and actuators used on paper machines. Initially, this improved equipment reduced variations in paper characteristics in the direction that the paper moved through the machine; increasingly improvements in these instruments have been "cross directional" (CD). The benefits include a substantial percentage reduction of rejects and of breaks, a major improvement in aspects of winder performance, and modest improvements in fibre use, steam savings, and machine speed.28 Indeed, incorporation of CD machine control will continue in the 1980s, especially to improve paper machine performance, as the approximately 960 CD control systems that were installed in North America at a cost of \$500 million between 1976 and 1984 represent just 20 per cent of the market. The pace of technological change in the forest-product industries has been rapid and has probably quickened within the past two decades. For Canadian forest-product firms technological options are varied, complex, and evolving.

Toward Reliance on Research rather than Resources

In Canada, innovation (including R&D) is a weak link throughout the industrial spectrum. The Science Council of Canada has argued that the competitiveness of Canadian industry, and ultimately, Canada's standard of living, depends increasingly upon technological innovation. Indeed, leading scientists now warn that Canada risks losing its sovereignty if it does not become more technologically sophisticated. Essentially, Canada needs to move from reliance on resources to reliance on R&D. This study urges such a shift for the forest-product industries.

Chapter 2

Research and Development

R&D can be looked at as a continuum of basic research to applied research to developmental research to technology transfer.¹

Basic research involves the search for fundamental laws and is the study of natural and social phenomena for its own sake.

Applied research applies the results of basic research to a specific process, material or device, on an industrial scale, to meet a commercial objective. As Furness points out, applied research emphasizes the identification of new products and processes and "usually carries an investigation up to the point of the first successful working model of a mechanical or electrical device, or through the usual glassware stage in a chemical synthesis."²

Developmental research is defined by Furness "as the application of technology to the improvement, testing, and evaluation of a process material or device resulting from applied research,"³ and at this stage scientists are increasingly replaced by engineers. It includes the design, building, and running of pilot plants, as well as the evaluation of the results of pilot plant work.

Technology transfer means subsequent application of developmental work to an industrial site. The installation and start-up of technology, especially if it is expensive, is likely to involve R&D personnel (whether or not they have been involved in the original R&D) including engineers who usually set product specifications, and design the process flow and scale of operations. It can require considerable modification to an organization or mill. Where a new facility is required engineers would design the layout, foundation, and infrastructure.

The time spent by R&D personnel on the operational problems of existing machines (for example, maintenance, quality control) is considered to be "troubleshooting" or "service work" and not part of R&D proper.

Innovation and Competitiveness

During the past 100 years, R&D in the forest-product industries has been "professionalized": industry sponsorship has become more important, expensive laboratories and teamwork have replaced the independent home-based inventor, and R&D has come to involve the application of formally learned scientific principles to whole systems.⁴ As Hull⁵ demonstrates, the transformation of the Canadian pulp and paper industry from one based on craft principles to one founded on science occurred between 1900 and 1930, when an elaborate research infrastructure was established by industry, government, and the universities. The pulp and paper industry changed from a wood-based industry controlled by craftspeople to a cellulose-based industry controlled by university-trained chemists and chemical engineers. The origins of science-based forestry and wood-products R&D can also be traced to this period.

Table 2.1 shows that forest-products are not a research-intensive industry. According to the table, during the 1970s R&D expenditures by wood-based firms in Canada accounted for 4–5 per cent of total in-house expenditures by industry. Thus, during the late 1970s, inhouse R&D expenditures were about 0.5 per cent of sales in pulp and paper firms, and even less in wood-processing firms. However, these data do not include the whole forest-product R&D effort in Canada: for example, the contributions that forest-product firms make to cooperative laboratories; forest-product-related R&D performed by chemical, electronics, machinery, and transportation firms; and related government and university R&D. Taking private sector efforts in isolation, Canada's forest-product R&D efforts are much smaller than those of competing nations such as Sweden and Finland.

of Dollars					
	1972	1976	1978		
Mines & Wells	27.3	40.9	50.3		
Chemical-based	95.41	162.3	204.1		
Wood-based	19.6	34.0	40.5		
(Wood)	(1.1)	(2.0)	(2.3)		
(Pulp & Paper)	(18.5)	(32.0)	(38.2)		
Metals	48.0	76.9	94.7		
Machinery & Transportation	100.0	146.7	220.0		
Electrical	114.1	166.0	195.8		
Other Manufacturing	7.6	9.1	11.6		
Other Industries	47.4	90.0	107.0		
Total	459.3	729.9	927.5		

Table 2.1: Total In-House R&D Expenditures, by Industry, in Millions of Dollars

Source: Statistics Canada, Industrial Research and Development Expenditures in Canada (Ottawa: Information Canada, 1978), cat. no. 13-203.

Because most R&D in the forest-product industries takes place outside Canada, to make correct technological choices individual firms must increasingly keep up with developments worldwide. Canadian firms are slow to innovate. They are rarely the first in the world to use a new technology.⁶ Some observers argue that Canadian firms should import technology in the form of equipment, licensing arrangements, and services because this would be cheaper for them than doing their own R&D, and that, where necessary, imported R&D should be adapted for the Canadian situation. However, this argument, which has been mooted frequently for Canadian R&D in general,⁷ ignores the dynamics that exist between innovation and technological leadership. Reliance upon imported technology and adapted R&D reinforces technological dependence at a time when technological leadership is critical to profitability and global competitiveness. Our American and Scandinavian competitors are wielding technology strategies that promote R&D and emphasize fully processed wood products and new process technology. For Canadian firms as well, healthy and vigorous indigenous R&D will be crucial to productivity and competitiveness.

Because they have continued, in this period of rapid technological change, to emphasize "proven" technology to manufacture a narrow range of standardized commodities, Canadian forest-product firms have declined in productivity and market-share relative to their major competitors. In the wood-processing industries, for example, Schuler argues that the Scandinavian countries, on the basis of more innovation, have achieved greater productivity increases than Canada has over the past 15 years.⁸ Certainly, sawmills in Scandinavia and the United States now convert a higher proportion of log volume into lumber products.⁹ Worldwide, Canada's share of forest-product export markets has declined from more than 30 per cent in 1960 to about 19 per cent in 1980, whereas countries such as Finland, Sweden, and the United States have increased their share.¹⁰

Canadian forest-product firms have not yet met the challenge of penetrating newly emerging, fast growing markets for higher valueadded products. In wood-processing, for example, "miscellaneous" wood products are negligible components of wood-product exports. Similarly, in pulp and paper, bulk commodities still predominate, although there has been a modest shift to higher value papers. In 1981, for example, newsprint still accounted for 49.2 per cent of paper and allied exports and "other papers" only accounted for 7.2 per cent; pulp and paperboard made up the balance. In Finland, by contrast, newsprint declined from 54 to 29 per cent of pulp and paper exports between 1959 and 1984 and the remaining exports were mostly fine papers.¹¹

A greater commitment to technological leadership and innovation is essential to maximize the quantity and value of products derived from the forest.

Forestry Sector R&D System

In Canada, forestry sector R&D is performed by forest-product manufacturing firms, cooperative (association) laboratories sponsored by forest-product manufacturing firms and by governments, equipment manufacturers, small specialized firms, federal and provincial governments, and universities.¹²

These institutions and the information pathways that exist both within and between them, to facilitate development, evaluation, and use of technology, make up the R&D system. The links, which may be private or public, formal or informal, hierarchial or lateral, unidirectional or multidirectional, are referred to as technological liaisons. They may or may not be free. In the latter case, the charge may be explicit or implicitly incorporated within the price of a broad set of goods and services.

The different kinds of research institutions enjoy different advantages in the R&D system¹³ (Figure 2.1). In particular, basic research is best performed by universities, applied research by the cooperative laboratories, process development by the equipment suppliers, new product development by forest-product firms, and technology transfer by equipment suppliers and forest-product firms.

Of course, reality is not quite so simple. For small firms, for example, the risks and costs of R&D may be prohibitive and so

Toreary Sector	Torestry Sector Red Trocess.							
	Basic Research	Applied Research	Process Development	New Product Development	Technology Transfer			
Universities	A	A	B	C	С			
Research cooperatives	В	A	В	В	С			
Industry R&D	С	В	В	A	A			
Equipment suppliers	С	С	A	С	A			

Figure 2.1:	The Com	parative Adva	antages of	Alternative	Agencies	in the
Forestry S	ector R&D	Process.	U		0	

Source: O.L. Forgacs, "The role of industry research," paper presented at *British Columbia's Future in Science and Research. Executive Seminar* sponsored by British Columbia Ministry of Education, Science and Technology, Delta River Inn, Delta, 25 July 1979, 4.

Note: A is strong comparative advantage; B is moderate comparative advantage; C is weak comparative advantage. Note that if government-run laboratories were to be included they would enjoy moderate comparative advantages in basic and applied R&D but would not be effective in developmental and technology transfer work.

cooperative and government laboratories invest in developmental as well as applied R&D. On the other hand, the desire for firm-specific advantages may push in-house groups in firms that can afford it to conduct applied and even basic research. Within universities, applied science faculties normally do developmental research and even pursue practical implications.¹⁴

Nevertheless within the forest-product industries there is an R&D system within which different kinds of organizations *should* play complementary if overlapping roles. Within this context, what needs to be expanded is the role of industry in-house groups in developmental R&D.

In-House R&D by Forest-Product Firms

Evolution and Location of In-House Laboratories

The oldest continuously operated company-owned R&D laboratory is probably that of CIP Research Ltd. which was set up at Hawkesbury, Ontario in 1923 by the then Riordan Pulp Co.¹⁵ Abitibi Power and Light (subsequently Abitibi Paper and now Abitibi-Price) also established an R&D facility in the 1920s at Sault Ste. Marie but this activity was closed down during the Great Depression and did not start up again until the 1940s. Several firms opened R&D laboratories in the 1930s and after the Second World War.¹⁶ Most recently, Canfor, in 1982 built a \$7 million pilot plant within its Grande Prairie plywood mill in order to conduct developmental research on aspen use.¹⁷

In-house forest-product R&D in Canada largely stemmed from a need to know more about pulping and paper-making processes.¹⁸ With a few exceptions, such as Canfor, current R&D operations grew up adjacent to pulp and paper and/or paper-converting plants.¹⁹

In the 1960s, however, several firms expanded and consolidated R&D activities at new locations in the suburbs of major metropolitan areas.²⁰ Conventional wisdom suggests that these sites are advantageous because, first, their location in relation to the firm's head office facilitates personal contact without too much casual interference. Second, they are located away from manufacturing operations, which limits the troubleshooting that R&D personnel are asked to do. Third, suburban sites share the economies and social advantages of large metropolitan areas including, in some cases, nearness to other types of R&D activities. A few R&D laboratories, at least one major facility and several smaller ones, remain outside metropolitan areas.

Although several firms have more than one R&D facility there is invariably one central laboratory and there may be satellite operations that provide specialized R&D. MacMillan Bloedel, for example, has set up its forestry research group at Nanaimo to be near the company's research forest and has relocated its building materials research group to a Vancouver sawmill to maintain close contact with a project that is in the developmental/technology transfer stage.

Over the years several foreign-owned companies have done R&D in Canada. Only twice have foreign companies established new R&D facilities and in both cases the forest-product operations of the American parents were entirely in Canada. In other cases, American-owned firms have taken over and closed down R&D operations in Canada. In general, foreign forest-product firms have not done much R&D in Canada.

The Size and Scope of Activities, 1980-84

Employment levels in in-house R&D by nine Canadian forestproduct firms dropped by 22 per cent from 582 in 1980 to 451 in 1984, including a proportionate drop in employment of professionals (Table 2.2). The results of the author's survey of 10 forest-product firms are consistent with these trends (Table 2.3). With respect to the distribution of these jobs by R&D activity, industry data for 1980 and 1983 reveal a marked concentration (60 per cent) in the pulp, paper, and

Table 2.2: Employ Forest-Product Fi	ble 2.2: Employment Levels in In-House R&D by Nine Canadian rest-Product Firms, 1980-84				
	1980	1981	1982	1983	1984
Total	582	551	516	461	451
Professional	259	263	230	207	196
% Professional	44.5	47.7	44.6	44.9	43.5

Source: Data collected by Domtar for the Canadian Pulp and Paper Association. The nine firms are Abitibi-Price, Belkin Paperboard, Canadian International Paper, Consolidated Bathurst, Domtar, Fraser Industries, MacMillan Bloedel, Ontario Paper, and Reed Paper.

Table 2.3: Employment Levels in In-House R&D by 10 CanadianForest-Product Firms, 1981 and 1984

	1981	1984
Total	568	454
Professional	252	203
% Professional	44.4	44.7

Source: Fieldwork, 1985. The 10 firms surveyed were Abitibi-Price, Belkin Paperboard, Building Products of Canada, Canadian International Paper, Canfor, Domtar, Fraser Industries, MacMillan Bloedel, Ontario Paper, and St. Anne-Nackawic. paperboard category, which includes pulping, bleaching, and deinking processes, and paper formation (Table 2.4). This concentration is also evident in data from the author's 1984 survey (Table 2.5). The absolute levels of employment in in-house R&D in such activities as forestry, wood products, and packaging are meagre. Moreover, although most jobs were lost in pulp and paper R&D the sharpest percentage declines were in less important categories.

In 1984 budgets for forest-product related R&D of the 10 surveyed firms were \$30.2 million: \$1.7 million above 1983 levels but close to 1981 levels. There is evidence that the decline in real terms has "bottomed out." The 10 firms obtained only \$1.5 million in 1984 from government, mostly in the form of Industrial Research Assistance Program (IRAP) grants from the National Research Council. The survey uncovered little interest in government funds for in-house R&D.

One firm used a mechanical rule and set R&D budgets at a minimum of 0.5 per cent of sales. Another had once attempted to follow a 1-per-cent-of-sales rule. Most firms fix budgets according to need as determined by discussions with representatives of the operating divisions and the chief executive officer. Apart from the smallest group,

Forest-Pro	orest-Product Firms by Major Activity, 1980 and 1983					
	Forestry	Pulp, Paper, Paperboard	Packaging	Wood Products	Environ- mental	Other
1980	46(7.9)	351(60.3)	33(5.7)	64(11.0)	40(6.9)	48(8.2)
1983	23(4.8)	297(64.5)	18(4.0)	42(9.0)	34(7.3)	47(10.4)
% Growth	-50.0	-15.4	-45.4	-34.3	-15.0	-2.1
o ===					D 4 D	

Table 2.4: R&D Employment (Percentage in Parentheses) in Canadian

Source: The data extracted refer to total employment in the R&D laboratories of forest-product companies.

Table 2.5: R&D Employment in 10 Canadian Forest-Product Firms by Major Activity, 1984

		Pulp, Paper,		Building	
	Forestry	Paperboard	Packaging	Products	Other
Total Employment	25	290	21	91	26
Professional Employment	11	129	10	42	11

Source: Fieldwork, 1985. The 10 firms surveyed were Abitibi-Price, Belkin Paperboard, Building Products of Canada, Canadian International Paper, Canfor, Domtar, Fraser Industries, MacMillan Bloedel, Ontario Paper, and St. Anne-Nackawic.

Note: Employment figures have been generated from percentage distributions of total rounded to nearest whole number.

and one other that was strongly oriented to technical services, R&D groups annually draw up one-year and longer-term plans. R&D priorities are worked out in corporate-wide discussions and R&D groups have to compete for their funds each year.

The orientation of in-house R&D is toward applied and developmental research: only one firm did basic research and that was only 5 per cent of its total research. If the two smallest R&D operations are excluded, the firms claimed that between 25 per cent and 85 per cent of their R&D was applied and between 15 per cent and 75 per cent was developmental. Six firms allocated 10-25 per cent of their staff and budget to technical services or troubleshooting. For the smallest R&D group, technical services constituted 75 per cent of activities, and one large laboratory allocated 50 per cent of its R&D effort to technical services for the operating divisions.

Rationale for In-House R&D

In noting the advantages of in-house R&D the respondents revealed common lines of thought:

We are able to respond to our needs in a timely fashion. If it's a small project there is too much red tape to go outside.

We can bring developments along at a schedule that is appropriate to us. A major investment with a 20-year time horizon cannot wait for Paprican. We can relate R&D to specific investment opportunities that make sense to us. Finally, we can relate to our particular window on the market. Technological shifts have to be detailed in the marketplace and related to capital investment projects.

R&D is a people resource for the rest of the firm. Divisions would have to strengthen their technological capability without us. We can more quickly respond to attack a problem; and while historically the industry was more process-oriented and open it is becoming more product-oriented and closed and proprietary information is becoming more important.

Close ties to business.

In-house R&D provides for rapid transfer of technology and is relevant to our business in the D stage so it is very commercial. It reduces maintenance costs; it provides marketing advantages; and the industry is becoming more closed. Teach yourself. If you go outside we have to educate them in our business which is expensive.

Results are specific to company.

The common theme is that in-house R&D provides firm-specific benefits that cannot be derived from association or government laboratories or universities.

Although the respondents acknowledged that sometimes forestproduct firms can be profitable without in-house R&D, they emphasized its benefits. One R&D director, for example, noted that savings due to research on corrosion paid for the firm's in-house R&D many times over. Four firms claimed their R&D was on the leading edge in the forest-products sector: one of these would not identify its area of expertise, but there is little duplication in terms of the strengths claimed by the other three. Thus one firm claimed expertise in paper finishing, another in pulp bleaching (and forestry work), and a third pointed to work on reconstituted wood, thermomechanical pulping, packaging, and corrosion. A fifth firm claimed that although it was not on the leading edge it was doing important developmental research with respect to chemithermomechanical pulping and de-inking processes. A sixth suggested that it had been on the leading edge and would be again but was not now. A seventh firm noted that it was a world leader in R&D on insulation but not on forest products. Although several firms had researched high-yield pulping processes, none saw duplication as a problem, in part because of the specific nature of each firm's needs and also because some competition in R&D is beneficial

Cooperative (Association) R&D

Although few forest-product firms in Canada support in-house R&D, the three main cooperative R&D laboratories are large and growing. The Pulp and Paper Research Institute of Canada (Paprican), Forest Engineering Research Institute of Canada (Feric), and Forintek were partly funded, in 1984, by 59, 45, and 142 corporate members respectively. The only other cooperative R&D laboratory, a small product development and plywood testing facility run by the Council of Forest Industries (COFI) in North Vancouver, has remained small and vulnerable to closure.

Paprican is most like a conventional industry association laboratory because it is largely supported by annual fees from forestproduct manufacturing companies. The federal government was closely involved in the establishment of Paprican five decades ago, but its importance to the organization is much less than to Feric or Forintek. Feric was the result of an amalgamation, in the early 1970s, of part of the Canadian Forestry Service (CFS) and the forestry group of Paprican; government and industry financing are of equal importance. Forintek was created by the "privatization" of the governmentrun Western Forest Product Laboratories and Eastern Forest Product Laboratories (the WFPL and EFPL) in 1979, but still obtains more funding from government than from industry. Although Paprican, Forintek, and Feric represent cooperative research ventures between industry and government (and in some respects, universities) their research priorities are strongly influenced by representatives from industry. In this sense, they function like conventional industry association laboratories.

Paprican and Forintek, and indirectly Feric, have their origins in government-owned and -operated forest-product laboratories. For example, Paprican, the oldest of the three organizations, originated in the Forest Products Laboratory (FPL) set up by the Dominion Government in 1913 on McGill campus in Montreal. It focused on timber testing and physics, wood preservation and distillation, and pulp and paper.²¹ The latter activity was thought to be considerably underfunded, however, and lobbying efforts were made to establish a separate centre for pulp and paper. Eventually an agreement was reached between the government, industry (as represented by the Canadian Pulp and Paper Association), and McGill University. The latter was chosen as the location of the existing FPL, because it had suitable facilities, basic research was to be emphasized, and because it held a bequest of \$200 000, which became available in 1925 and which McGill decided to use to establish a Department of Industrial and Cellulose Chemistry. The federal government also played a key role in the creation of Paprican: over four years, 1925-28 it provided \$36000 a year, on condition business contributed \$20 000 a year.²² Subsequently, the government increased its contribution to about \$100000 a vear until the mid-1950s when annual grants for operating requirements were replaced by a capital grant in the form of the Pointe Claire facility. Similarly, the federal government provided Paprican with its recently established Vancouver facility.

Feric began operations in 1975 and was essentially a spin-off from Paprican. It replaced the latter's woodland section, made up of a silvicultural group and a logging group, which was disbanded in 1971. Feric's mandate relates to wood harvesting, but in practice its R&D has expanded to embrace reforestation and tree planting.

Forintek was created when the Eastern Forest Products Laboratories and the Western Forest Products Laboratories, both part of the Department of Environment until 1979, were privatized following industry and federal government calls²³ for a stronger industry role in forest-product R&D. The privatization plan was controversial²⁴ and government funds have remained important to Forintek, as they have to Feric.

Size and Scope of Operations

In 1984 Paprican, Forintek, and Feric employed in excess of 500 people and their budgets totalled over \$30 million (Table 2.6). The funding of cooperative research is slightly larger than in-house R&D budget levels and it is growing. Between 1979-80 and 1984-85 the combined budgets unadjusted for inflation increased by 60 per cent and Paprican's almost doubled. Contributions from industry members account for about 84 per cent, 50 per cent, and 25 per cent of the revenues of Paprican, Feric, and Forintek, respectively. These contributions vary by size of firm, and firms with in-house R&D are also the biggest contributors to cooperative research. Paprican supplements its funds from members' fees mainly by providing technical services on contract and just 4.7 per cent of its funds are from government sources. In contrast, Feric and Forintek receive about 50 per cent of their funding from the federal government, while Forintek receives a further 25 per cent from the provincial governments of Alberta, British Columbia, Quebec and, most recently, New Brunswick and Nova Scotia.

Laboratories, 1979 and 1984							
	Buc (\$0	lget 00)	Emplo	yment			
	1979-80	1984-85	1979-80	1984-85			
Paprican	9 950	17010	260	320			
Feric	2 000	3 394	48	50			
Forintekª	8 800	11 416	200	200			

Table 2.6. Budget and Employment Levels in Three Cooperative

Source: Various sources including annual reports and fieldwork, 1985. a Formerly Western Forest Product Laboratories and Eastern Forest Product Laboratories.

Paprican, Feric, and Forintek have boards of directors. Paprican and Forintek have research program committees and Feric has the National Advisory Committee on Forest Engineering Research (NACFER) to vet and control research priorities. Feric and Forintek also have eastern and western subcommittees. Although the boards and research committees draw from industry, government, university, and the organizations themselves, representatives from industry dominate. In 1985 the boards of directors of Paprican, Feric, and Forintek had 20, 18, and 23 members respectively of which 12, 11, and 14 were from industry and just two, three, and six from government. Clearly, these organizations are primarily oriented to the needs of industry.

Rationale

The three institutions have distinct research foci. Paprican works on a wide variety of projects related to the manufacture of pulp and paper; Forintek focuses on wood-processing technology and wood products; and Feric deals with wood harvesting and silviculture. Paprican has the strongest research capability of the three associations, which is not surprising given its focus on technologically sophisticated pulp and paper activities. Paprican essentially focuses on "pre-commercial" basic and applied R&D, and developmental R&D that is either too expensive for individual members or has industry-wide applications of the kind that cannot be appropriated by individual forest-product firms. Paprican also provides industry with a supply of highly trained scientists and engineers mainly by sponsoring graduate student research, especially at McGill and, since 1978, at the University of British Columbia. About 80 per cent of Paprican's R&D is processoriented. Paprican does research into matters of public interest; maintains a pulp and paper library; provides computer-based information retrieval services, calibration services and standards, and research consultation; promotes the awareness of technical needs by means of publications and seminars, for example; and provides pulp and paper training courses for engineers.25 In terms of R&D, over the past 20 years, the most significant shift in Paprican's focus has been toward a greater emphasis on developmental research and technology transfer and, most recently, on product R&D. These trends have led people to ask whether Paprican complements or substitutes for in-house R&D.

The R&D managers who responded to the author's survey generally felt that Paprican was becoming more important and that the establishment of a facility on the campus of UBC in 1987 would further this trend. The continuing growth of Paprican within the overall forest-product R&D system generates mixed reactions. The managers of the smallest R&D programs are generally in favour. Several other survey respondents, however, expressed concern that Paprican is becoming too service-oriented and moving away from its traditional role as supplier of basic and applied research to the pulp and paper
industry. Many firms perceive Paprican as an alternative to in-house research.

Feric's mission is to conduct R&D to improve the efficiency of wood-harvesting operations and to minimize the cost of wood used in manufacturing. Prior to Feric, diverse local conditions and the importance of small businesses in logging and the manufacture of logging equipment had meant meagre and fragmented R&D on the engineering technology used in wood harvesting. Feric has sought, first, to provide a Canada-wide framework for R&D to improve components, machines, and systems in all phases of wood-harvesting operations; second, to search worldwide for relevant concepts and encourage their adoption in Canada; and, third, to disseminate its results in published papers and field work.

Feric's R&D is strongly developmental and site-specific. Feric has been almost exclusively concerned with technology transfer and with promoting "best practice" technology, wherever it originates. Although it maintains some contact with the R&D departments of equipment suppliers, Feric concentrates on R&D that supports wood-harvesting business and substitutes for their in-house R&D.

Forintek conducts R&D and provides services in codes and standards, technology transfer, and training and education for the Canadian wood-products industry. Forintek estimates about 60 per cent of its work is R&D and 30 per cent codes and standards. Forintek was created to encourage greater sensitivity to the needs of the woodproducts industry, and its R&D has been more developmental and has involved more technology transfer than that of its predecessor laboratories.²⁶

Forintek sees itself providing technological leadership to the wood-processing industry in five ways:

- by providing a "technological bridge" between forest manager and manufacturer at a time when the nature of the forest is changing rapidly.
- by stimulating higher levels of productivity and wood utilization in the mills.
- by providing the technical expertise to develop and influence codes and standards that are in the interests of Canadian wood products and wood designs.
- by increasing the competitiveness of wood products through the development of new products and processes.
- by educating industry about technology through courses.

Like Feric, Forintek strives to promote adoption of the best technology that has been developed anywhere in the world. In addition, Forintek, sometimes in cooperation with universities, has established long-term R&D programs in such fields as biotechnology.

In-House R&D by Equipment Suppliers

Size of Activities

Among the 37 respondents to the author's second survey, the level of commitment to product innovation, product adaptation, and in-house (in Canada) R&D varied. In 1984, 19 firms stated that they formally conducted R&D. They employed 135 professionals and technicians of which 75 were professional scientists and engineers (Table 2.7). The size of R&D departments varied from one permanent professional employee (four cases) to 42 professional and technical employees. Only six firms employed 10 or more professional and technical employees, whereas 11 firms had five or fewer professional and technical employees. In 12 firms the professional and technical staff spent at least 50 per cent of their time in R&D, and in the leading six firms all the recorded employees were fulltime. Some firms also employed engineering design teams. The decline in R&D employment from 1981 to 1984 from 182 to 135 employees was largely accounted for by one of the leading six R&D performers, which consolidated two R&D groups. Another firm eliminated its R&D group of nine professionals in this period. Most other R&D groups remained the same or changed slightly. One leading R&D performer expanded its group significantly.

			R&D Employment				
	R&D Budget (\$000)		Professional		Professional and Technical		
	1983	1984	1981	1984	1981	1984	
Top 6 Top 10 Totalª	6 350 9 550 9 900	6 900 7 610 7 893	81 96 99	62 70 75	145 169 182	103 120 135	

Table 2.7:	R&D	Budget	and Em	ployment	Levels	among	Sampled	Equipm	ent
Suppliers		U U				U	-		

Source: Author's survey of 130 equipment suppliers. ^a Twelve firms reported their R&D budgets, 19 firms reported R&D employment.

The 12 firms that reported their R&D budgets spent just \$7 893 000 in 1984 (Table 2.7), and the total R&D budget of the 37 responding equipment firms, including estimates for those that did not report budget, was unlikely to be higher than \$10 million. In the same year, 31 of the sampled firms reported total sales of \$616.5 million. That is,

expenditures for R&D in 1984 could not have been higher than 1.6 per cent of sales and they were almost certainly lower. The six firms with the largest R&D programs, however, invested at least 2.5 per cent of sales in R&D and one firm allocated 7.5 per cent. Indeed, the R&D of these six firms differs from that of the others in size, continuity, and diversity of effort. Government assistance for R&D by equipment suppliers is meagre.

The R&D of the sampled firms is product oriented, strongly developmental, and related to their perception of market needs. Firms only do R&D that involves their current mix of products. Of the six firms that spend the most on R&D, three are in logging, one in wood processing, one in electronics, and one in pulping. The next four firms concentrate on either logging or wood-processing technology.

As noted, a few equipment suppliers that perform R&D did not respond to the survey at all. Even so, a generous "guestimate" is that in 1984 all Canadian-based forest-product equipment suppliers invested no more than \$12-\$15 million in R&D and employed no more than 250 professionals and technicians.

Technology Strategies

Technology strategies, as reflected in formal R&D efforts, vary considerably among equipment manufacturers. Leading equipment suppliers invest in R&D as a source of competitive advantage and are normally strongly export oriented. They recognize that competitiveness in a high-cost region such as Canada depends upon product innovation.²⁷ The six largest have strong in-house programs that employ a minimum of 10 professional employees. They budget annually for R&D and formulate annual and long-term plans. These firms are prepared to evaluate competing R&D proposals: for example, in 1984, one firm chose six projects out of 44 that had been proposed. The six leading R&D performers are companies run by managers and include four foreign-owned subsidiaries that are in effect the forest-product equipment divisions of their parent companies.

There are also foreign-controlled subsidiaries, whose parent firms also manufacture forest-product equipment. Some of these branch plants have small R&D groups that adapt products for the Canadian market and transmit ideas back to the central laboratory; and others rely entirely on imported R&D. Some companies, both entrepreneurial and managerial, simply do R&D "when required" in order to maintain their work force and market share. As one respondent stated, "[An] employee size of 150 is comfortable for us." In many small companies annual budgets for R&D are rare, and when R&D is performed it tends to be strongly market driven and to focus on one product. One, by no means atypical, firm said developmental work only began after an idea had been accepted by a customer so that the firm was "never left with a prototype." For firms that see R&D as an occasional activity to maintain the status quo, acquisition by a more growth-oriented firm with a continuous R&D cycle can be a source of unanticipated discomfort. For example, a new parent company may insist that investment in R&D be determined as a fixed percentage of sales.

In-House R&D by Chemical Suppliers

The pulp and paper industry is a major user of chemicals, and chemical companies have a long history of innovation especially with regard to pulping and bleaching processes. Within Canada the largest chemical-based pulp and paper R&D laboratory is operated by CIL in Mississauga, and ERCO also has been involved in R&D especially through contract work at the University of Toronto. The major chemical suppliers, including CIL, are foreign-owned. With the exception of CIL, these companies have centralized their R&D laboratories outside Canada.

CIL already had a long-established R&D laboratory with expertise in pulp and paper and mineral extraction when British-based ICI acquired the firm in 1954. CIL's first research centre was established at MacMasterville, Quebec in 1916. A new pulp and paper chemicals research laboratory was also established there in 1953. In 1980 it was relocated to Sheridan Park, Mississauga (adjacent to the R&D centre of Abitibi-Price).

CIL has retained responsibility for specific areas of ICI group research including pulp and paper. Although it is unusual for a broadbased chemical manufacturer such as CIL to pursue R&D in an area not directly related to its own activities, the pulp and paper industry is an important market for bulk chemicals such as chlorine and caustic soda. Pulp bleaching has been a major research subject since 1953. Developments in the 1950s and 1960s led to investigation of oxygen pulping and to the discovery of AQ pulping technology, which has been patented worldwide and is regarded as a major innovation. At present, bleaching and pulping are the chief interests of CIL's Chemical Research Laboratory.

In 1984 the two chemical firms in Canada with in-house R&D on pulp and paper likely budgeted \$4.5 million, and employed about 40 professionals and technicians.

Specialized R&D Performers

Although not many small R&D firms serve the Canadian forestproduct industries, here are a few examples, principally from British Columbia, of the types of individuals and companies that do specialized R&D for the forest-product industries.

Independent Inventors

The "independent inventor" is an academic or a government scientist who seeks to commercialize an invention. For example, while on the forestry faculty at the University of British Columbia, J. Walters has patented various machines including a tree planter. Typically the independent inventor retains his or her affiliations unless an invention becomes spectacularly successful.

Technical Entrepreneurs

"Technical entrepreneurs" sever their connections with large companies and set up spin-off firms. For example, C.M. Mitten had worked in a senior capacity in the R&D department of a sawmilling equipment manufacturer for about 20 years. Recently he set up his own spin-off company, Cetec Engineering in British Columbia's Discovery Park at Burnaby to develop, among other innovations, a "smart saw." The "smart saw" includes a circular saw blade that can regulate its own temperature. It was marketed in 1984 and the company expects sales of \$20 million over the next 10 years. More recently, Cetec has been working on a rimsaw that it claims "could revolutionize the sawing industry's cutting technology."28 Using funds from the federal government, Cetec has developed a prototype rimsaw with only one moving part, which will cost just half the price of a contemporary type of band mill. Trials have been run in cooperation with MacMillan Bloedel, and Cetec believes its rimsaw could replace 80 per cent of existing band mills. The company plans to license this and other products to a local equipment manufacturer.

R&D Service Companies

An example of an R&D service company is provided by Econotech, located in Richmond, British Columbia. Econotech was originally the R&D division of Columbia Cellulose (Cocel), which was set up at Prince Rupert and relocated to Vancouver in the mid-1960s because of recruiting difficulties. At its peak Cocel's R&D division employed 80-90 people and was largely concerned with pulping processes, especially dissolving pulps that are used in a variety of products including cellophane, plastic handles, and cigarette filters. Cocel, a subsidiary of the Celanese Co. of New York, was the conglomerate's only internal source of dissolving pulps. Whereas Cocel's R&D focused on pulping, the central laboratory of Celanese in New York focused on the pulp-converting stages.

As Cocel began to lose money in the late 1960s the R&D staff became embroiled in operational problems at the expense of longterm research regarding dissolving pulps. When it became clear Cocel would close its R&D division, two employees in 1972 purchased the laboratory and created Econotech. Then the company had nine employees; by 1978 it had 20. Econotech still specializes in pulping R&D and concentrates on developmental work and technology transfer. Although Econotech does provide "consulting services" on operational matters, it emphasizes independent evaluations of pulping processes utilizing its own equipment, which includes complete pilot plant facilities for pulping and bleaching.

Econotech's customers include equal numbers of large companies, for which it conducts "overload" R&D, and small firms, which may lack the expertise to do their own R&D. Virtually all work is done under contract to forest-product firms, capital goods manufacturers, and consulting engineers. About 50–70 per cent of revenue is generated within British Columbia.

There are three explanations for Econotech's growth and its ability to compete internationally. One, it has a high level of expertise in dissolving pulps, a field where there are few competitors to begin with. Two, Econotech claims to be able to maintain confidentiality. All employees sign secrecy agreements and sometimes technologists are themselves not fully informed about the problem they are investigating. Three, Econotech has accumulated considerable experience in a variety of mill environments throughout North America.

Another British Columbia-based spin-off company is Coast Mountain Consulting of Nanaimo, which designs software packages for use in forestry. All Coast Mountain's original personnel came from MacMillan Bloedel's Woodland Services in 1982, when MacMillan Bloedel was cutting back. MacMillan Bloedel had created the group called Computer Assisted Forest Engineering or CAFE in 1975 to provide the company with a series of programs on various forestryrelated tasks. Coast Mountain continues to serve MacMillan Bloedel, but also sells to other corporations in the United States and Canada.²⁹ Software packages range in price from \$300 to \$20 000.

Government and University R&D

Canadian governments, especially the federal government, and universities have traditionally done R&D for the forestry sector.³⁰ In

contrast to in-house R&D by forest-product firms and equipment manufacturers, these activities are mostly forestry related and only peripherally concerned with manufacturing.

Let us look first at forestry-related R&D, which is the only sort the federal government does. Since the privatization of the EFPL and WFPL. the main laboratories controlled and operated by the federal government have been those of the Canadian Forestry Service (CFS). At present, the CFS operates an extensive R&D network that includes the Petawawa National Forest Research Institute, the Forest Pest Management Institute, and six regional laboratories in St. John's (Nfld.), Fredericton (N.B.), Ste-Fov (P.Q.), Sault Ste. Marie (Ont.), Edmonton (Alta.), and Victoria (B.C.). Although some of the laboratories have longer histories, this system was substantially created, and its mandate clarified, amidst considerable controversy, during the 1960s. Proponents argued that university research was limited, lumber industry research virtually non-existent, and provincial government research concentrated on the problems of forest administration.³¹ As expected, the research programs of the regional laboratories reflect mainly local priorities whereas the institutes focus on matters of national concern.

In 1977–78 the federal government spent \$31.0 million on forestry research, mostly in the laboratories of the CFS.³² At that time, these laboratories employed approximately 370 professionals.³³ During the review by government and industry that led to Forintek, CFS research came under scrutiny and in 1979–80 federal research expenditures on forest management were reduced, even in current dollar terms, to \$30.1 million.³⁴ The system was not modified substantively, however, and federal funding increased to \$58.9 million in 1983–84. Provincial funding, although lower and concentrated in Quebec, Ontario, and British Columbia, also increased. As a result, total government expenditures on forest management R&D rose from \$40.0 million in 1979–80 to \$77.2 million in 1983–84.

Finally, universities do forestry-related research not only at the faculties of forestry at the universities of Laval, New Brunswick, Toronto, and British Columbia, and at the newer schools at Lakehead University and the University of Alberta, but also in departments of applied sciences and biology.³⁵

R&D by governments and universities into forest-product manufacturing processes is more limited. The federal government does not do any. The provinces of British Columbia, Ontario, and Quebec have set up industrial research organizations that do R&D related to forestproducts (and forestry). However, the Forest Products Section of the Ontario Research Foundation (ORF) has declined to the point where in 1984 it employed only four professionals and had a budget of \$450 000, of which only 18 per cent came from the Ontario government. Most of this work is pulp and paper related. In British Columbia, the B.C. Research Council's R&D is fragmented and depends largely on contracts from government and industry. The Centre de Recherche Industrielle du Quebec (CRIQ) has been more active. In 1979, for example, CRIQ spent \$4.5 million on forest-related R&D, mostly to do with wood-processing and logging equipment.

Several universities, including the forestry schools, have also contributed to forest-product R&D. Mention should be made of McGill's long-standing relationship with Paprican and the well-known work of the chemistry department at the University of Toronto on pulping processes. In general, however, universities have done little forestproduct R&D.

Technological Liaisons within the Forestry Sector

The groups that constitute the forestry sector's R&D system in Canada exchange information with each other and with the business operations of forest-product manufacturing firms and equipment suppliers. These links are referred to here as technological liaisons. Figure 2.2 summarizes the nature of these information exchanges from the perspective of a forest-product firm's in-house R&D group. Naturally, the pattern of information exchange differs for laboratories in, for example, R&D service companies or government departments. The particular pattern of information exchange is an important determinant of the location of a laboratory.

Technological liaisons can be used to disseminate information about existing technology or to generate new information through research collaboration. In the former case the cooperative research laboratories play important roles especially through the publication of research results (sometimes only for members), seminars, and demonstrations. For example, Forintek has been active in transferring technology by its "seminar on the road program." Since 1983, scientists at Forintek's Vancouver-based laboratory have offered seminars throughout western Canada on such topics as lumber size control, lumber drying, sawmill improvements, saw maintenance and control, and on improving productivity through microelectronics. In Quebec, Forintek is cooperating with CRIQ to provide similar services. The annual meetings of the technical section of the Canadian Pulp and Paper Association (CPPA) provide an important forum for discussion of technological developments in the forest-product industries.

Other important ways in which information on existing technology is disseminated are patents, mill visits, and engineering consultants.³⁶

Figure 2.2. Technological Liaisons of an R&D Laboratory in a Forest-Product Firm



CORPORATE PRODUCTION ACTIVITIES

New information can be generated by research collaboration between either the in-house R&D groups of forest-product manufacturing firms and equipment suppliers, or between these groups and cooperative laboratories³⁷ and/or universities, or between the cooperatives and universities. When forest-product firms and equipment suppliers collaborate, the R&D is strongly developmental, and largely limited to the testing of prototypes, and arranged on a project-byproject basis. Collaboration between the cooperatives and equipment suppliers rests on a similar basis. In addition, Paprican recently introduced Allied Industry Support Programs, which permit equipment suppliers to sponsor or entirely fund development work at Paprican.

The three cooperative research laboratories collaborate with individual universities, notably Paprican with McGill and UBC, Forintek with UBC and Laval, and Feric with UBC. Company R&D groups also tap university expertise from time to time and the federal government is trying to increase these links. MacMillan Bloedel, for example, has contracted a computing scientist at Simon Fraser University to develop log-scanning technology.

Individual forest-product firms monitor and absorb technological information in a variety of ways. For a few firms, in-house R&D groups provide an important, sophisticated and critical "window" on the technological environment. But for these firms, and even more for those firms lacking in-house groups, other mechanisms for keeping up with technological change are necessary. Within the Canadian forest-product industries such mechanisms have traditionally included attendance by selected individuals at technical conferences, library research, visits to mills, and advice and reports from the research cooperatives and consultants. The effectiveness of these mechanisms obviously depends upon the skill and participation levels of managerial and shop-floor employees and the extent to which firms are willing to support them. A few firms are highly regarded throughout the industry for the quality of the "technical" personnel at individual mills. Other firms rely heavily on one or two experienced individuals for keeping abreast of technological change. There are also variations in the commitment of firms to upgrading the skills of individual employees although, until recently, there were few systematic attempts along these lines. Yet the ability to incorporate and adapt new technology depends upon the technical aptitude of individual production-line and maintenance employees.

There is also the question of the best way to share information within the firm. Traditionally firms have relied upon informal contacts as well as established hierarchial lines of communication. Overall, the flow of technological information has been rather ad hoc. As the technological environment has become increasingly complex, however, a few firms have seen the value of formal channels for communicating technological information. Abitibi-Price has recently established a "technology transfer unit" whose purpose is to coordinate the flow of technical information within the firm and plan personnel requirements related to the firm's evolving technical needs and services.

Trends in Forest-Product and Forestry R&D, 1968-84

In 1968 Smith and Lessard³⁸ estimated that R&D expenditures for the forest-product industries and forestry amounted to \$54 million, a figure that does not include expenditures by the equipment supply industry. Solandt³⁹ estimated that in 1979 \$115 million was spent on R&D on forest-products and forestry including almost \$12 million by the equipment supply industry. Neither estimate includes a correction to university and government expenditures to take into account general overhead costs. Because Solandt estimated that in real terms an R&D expenditure of \$54 million in 1968 would be the same as \$151 million in 1979, he concluded that there had been a substantial reduction in Canada's forest-product R&D between 1968 and 1979.40 He noted that strong declines had occurred in federal government R&D expenditures both for forestry and forest products and in in-house R&D by forest-product manufacturing firms; provincial government expenditures were identified as the only growth component (and they have always been relatively minor).

There are some interesting recent trends in forestry R&D. First, the decline in government support that occurred during the 1970s has been arrested. Second, overall expenditures remain small, given that Canada is a forest nation, and third, the lack of any concerted effort by industry is disappointing. With respect to forest-products R&D, the most noticeable trend since 1979 has been the relative growth of the cooperative laboratories, much of which has been financed by government rather than industry. With the possible exception of Quebec, provincial government direct support for forest-product R&D remains limited and has probably declined. The steady decline in the 1970s of in-house R&D by forest-product manufacturing firms has been halted but not reversed. On an optimistic note, some in-house R&D laboratories are in a stronger position now than in 1981 following the worst recession in 50 years and one group has been established. The labs have proved their worth in a poor business climate. On a pessimistic note, there are few in-house laboratories and overall employment and budget levels are small. Between 1979 and 1984 in-house R&D by equipment suppliers in Canada fell in real terms. At least two such labs folded in this period and no compensating growth took place in the industry.

Chapter 3

The R&D System and How It Works

There is no doubt that the way the R&D system functions is complex. Not only are the steps in the R&D continuum difficult to pinpoint for any specific innovation, but also the evolution of an innovation depends on many different individuals and groups (within and outside the firm) and how they interact, and also on such contingencies as industrial relations and investment plans. R&D can also fail or take an inordinately long time to pay off. Before considering how the R&D system *does* yield new or improved processes and products, it is pertinent to look at some of the risks.

Delayed Returns and the Possibility of Failure

The history of the chain saw is a good illustration of how long it can take for a new invention to be successful. After attempts had been made to develop models that would be more efficient than the axe and back saw, the chain saw as we know it was invented in Germany in 1840.¹ However, it was developments during the Second World War, notably with respect to light metal technology and sophisticated light air-cooled engines, that allowed the development of a usable, reliable machine. Between 1939 and 1960, the lightest chain saws dropped from 38 kg to 9 kg and productivity increased by 40 per cent.

If it is assumed that the chain saw was used commercially soon after 1850 then its subsequent rate of diffusion was extremely slow prior to 1950. Indeed, it was only after substantial R&D in other sectors of the economy (such as the aircraft industry) and the transfer of this technology to chain saw production that effective diffusion became possible. (The fact that there was much spare plant capacity in 1945 also encouraged production of chain saws.) After 100 years of being "unsuccessful," the chain saw eventually revolutionized the logging industries.

There have been other products and processes that were never commercialized or did not prove commercially successful for many years. For instance, articulated frame-steered skidders for wood harvesting, introduced in 1916, did not become popular until the 1950s after hydraulic circuitry was developed.

Many other projects failed. Some were probably given up too soon. Silversides² argues that this was likely the case with respect to

the Beloit harvester, a machine, invented by two Canadians, that limbed the standing tree, cut off its top, severed it from its stump, and placed the treelength in a pile. The Beloit Corporation of Wisconsin manufactured it between 1965 and 1970 and sold 40 units. Yet in 1982 half these machines were still in operation. The Arbomatik System and the Koering Shortwood Harvester are other examples of woodharvesting machines developed in Canada that were only manufactured briefly.

Some failed for technological reasons. Doubtless many technological failures are never publicly discussed. Tillman³ suggests that technological risk in the forest-product industries becomes substantially smaller at each stage of development. Other projects were abandoned for financial reasons.

The Role of In-House R&D by Forest-Product Firms

The in-house R&D groups of forest-product companies develop mostly process-oriented and firm-specific technology. Details of technology development are hard to find and the effects of such innovation are difficult to measure. To gain some insights into this process, the author asked R&D managers at 10 firms about recent "important" innovations developed and commercialized at their firm. Six firms provided information on 10 "important" innovations within the past 10 years (Tables 3.1 and 3.2). The managers' comments are subjective and must be interpreted cautiously.

	Period of		R&D Costs		
Project Cost (\$M)	Development (Years)	Area of Innovation	As % of Project Cost	\$000	
1	3(2) ^a	Building materials	40	210	
1	6(5)	Paper quality	90	650	
1-5	17(13)	Pulping	90	2700	
1-5	13(3)	Bleaching	10	300	
5-10	8(4)	Pulping	20	2000	
>10	11(8)	Pulping	9	2 500	
>10	11(9)	Pulping	19	2 500	
>10	5(2)	Pulping	30	7000	
>10	15(10)	Pulping	20	3 000	
>10	7(2)	Pulping	10	3 000	

 Table 3.1: Selected Characteristics of "Important" In-House Technological

 Developments since 1970 by Six Forest-Product Firms

Source: Fieldwork, 1985.

^a Numbers in parentheses represent years until prototype developed.

	Average Period of	R&D Costs					
Project Cost (\$M)	Development (Years)	As % of Project Cost	Average \$000	Median \$000			
<10	9.4 (5.7) ^a	18	3 3 3 3	2750			
>10	9.8 (5.4)	58	965	475			

 Table 3.2: Summary Characteristics of "Important" In-House Technological

 Developments since 1970 by Forest-Product Firms

Although R&D procedures vary considerably from one project to another, several key points regarding "important" in-house technological innovations may be made. First, almost all recent major innovations by Canadian forest-product firms have involved new kinds of pulping processes; thus seven of the 10 projects involved pulping and an eighth involved the bleaching of pulp. All five projects costing at least \$10 million involved new pulping processes that allowed higher yields and/or replaced increasingly expensive kraft chemical pulp. Higher wood costs, due to increased scarcity and environmental problems, and the increasing cost of the kraft pulp process led firms to develop mechanical pulping and/or new ways of chemically treating wood fibre to generate pulp. Each firm developed a pulping method appropriate to its timber supply and the problems facing its mills, and duplication of effort is not seen as a problem. One firm is attempting to license its technology to others.

Second, for the projects costing more than \$10 million, set-up costs were uniformly high, and just 18 per cent of total costs was allocated to R&D. In contrast, for cheaper projects the proportion allocated to R&D varied considerably so that the average figure of 58 per cent is not representative. Third, the projects were in the R&D pipeline for almost 10 years on average, and Table 3.1 shows no difference in period of development between projects that cost more or less than \$5 million. However, the two projects that cost less than \$1 million took only 4.5 years, suggesting that a positive linear relationship between the cost and the period of development of projects may exist for cheaper projects, but that at a cost of \$1 million, and possibly less, the relationship disappears.

Fourth, it generally took a long time to research, develop, and commercialize the projects. The average time until the point of prototype development was 6.1 years and the subsequent period to commercialization 3.1 years. Comparison of periods of development may not be that meaningful, in part because of varying personnel requirements and availability, in part because of varying research requirements. Projects may also be temporarily shelved, especially those with substantial set-up costs. There were considerable differences in the periods of development for equally expensive projects. One firm, for example, developed two distinctive pulping processes for different locations and was able to shorten the development time of the second process by drawing upon research done for the first. In another project, a firm avoided financial delays by commercializing some elements of an "important" innovation before finishing it.

Fifth, for the more expensive projects, and for pulping projects in general, R&D costs cluster around \$2.7 million. The only exception to this occurred because one firm had to construct an entirely new pilot plant.

As scant as they are, these data undermine the idea of a continuum of R&D costs for projects. My survey also showed that in-house R&D has been oriented to firm-specific requirements. In-house projects were applied within the firm, two at more than one company location; one project was also sold to another firm. Although the firms do take out patents, and contemplate selling their technology, the main thrust of their R&D is directed toward their own operations.

A small amount of in-house R&D by forest-product firms has been product-oriented. An example is MacMillan Bloedel's Parallam, a building material that its makers claim is stronger than conventional lumber, with a bending strength that exceeds glue-laminated lumber. The company began research in the early 1970s and built a \$10-million prototype plant in 1982. Although some Parallam was produced for Expo in 1986, its full commercialization awaits investment in new plant and completion of various marketing initiatives.

The Role of In-House R&D by Equipment Firms

Equipment suppliers have traditionally been a significant source of new technology in the forest-product industries,⁴ and to the extent that they provide new equipment they are invariably involved in technology transfer. In Canada, few equipment suppliers conduct basic, applied, or developmental R&D. They rely upon foreign R&D to generate new products that are obtained from parent companies, from other companies by means of "arm's-length" licensing arrangements, and by imitation. In firms that do conduct basic, applied, or developmental R&D, the efforts are sporadic.

Among the sampled firms, slightly more firms (23) claimed that they had developed a new product over the last five years or so than the number of firms (19) that claimed some form of in-house R&D. Sixteen firms provided details on selected characteristics of their most recent important in-house innovation (Table 3.3). R&D performed in Canada by equipment suppliers takes less time and costs less than the in-house R&D of forest-product firms. The period of development to the prototype stage varied from one month to 24 months, with the average time being 11.7 months. From prototype to commercialization averaged about seven months. In Canada, the cost of developing "important" new forest-product equipment is normally in the \$500 000 to \$1 million range, which is significantly lower than the cost of "important" innovations developed by forest-product firms. For reporting equipment suppliers, their first customer was located either in Canada (10 firms) or the United States (6 firms).

for the Forest Inc	for the Porest industry by Equipment Suppliers								
Project Cost (\$000)	Period of Development (Months)	Area of Innovation	Location of First Customer	R&D Costs as % of Total Costs					
A. Top 6 R&D Performers									
100-500 (143) 100-500 500-1000 500-1000 (900) 100-500 500-1000 (600)	13(8) ^a 36(12) 29(24) 30(18) 14(12) 18(12)	Wood processing Pulping Wood harvesting Wood harvesting Electronics	U.S. Que. B.C. Ont. Ont. Ont.	99 90 40 50 70 20					
B. Next 4 R&D Performers 500–1000 100–500 50–100 ^b 50–100	24(?) 40(24) 48(24) 13(8)	Wood processing Wood processing Paper-making Pumps	U.S. B.C. U.S. Ont.	80 80 100 57					
C. Others 100–500 50–100 5–20 50–100 100–500 20–50	8(7) 6(1) 6(1) 18(6) 36(12) 9(7)	Wood processing Wood processing Wood processing Wood processing Wood drying Electronics	Man. B.C. U.S. Ont. U.S. U.S.	50 30 10 15 55 80					

 Table 3.3: Selected Characteristics of the Most Recent In-House Innovation

 for the Forest Industry by Equipment Suppliers

Source: Fieldwork, 1985.

^a Numbers in parentheses represent months until prototype developed.

^b Firm terminated its R&D program in 1984.

Typically the greater the project cost the longer the period of development. Moreover, the longer and costlier projects were normally undertaken by the leading (10) R&D performers. For most firms R&D costs are relatively important components of overall project costs. Eleven firms, for example, claimed that at least 50 per cent of their project costs resulted from R&D (Table 3.3). The untabulated aspects of project costs are as follows: licensing costs are negligible and only five firms claimed to have any licensing costs at all; marketing costs are important and 12 firms claimed that marketing costs were at least 25 per cent of the total; and set-up costs are reasonably important.

Those interviewed expressed mixed views regarding the patenting of new products. Although all 10 leading firms had taken out patents over the last five years, only two had taken out more than five. Among the entire sample 10 firms thought patents to be "not very important," seven thought them "very important," and the remaining 20 thought them "slightly" or "moderately important." In part, foreign ownership explains the differences: subsidiaries rarely take out patents themselves but their parent companies do. Nevertheless patents constitute a sensitive issue. On the one hand, firms favour patents to afford protection in the marketplace, to reinforce the company's reputation as a technological leader, and to cater to the desires of individual scientists. On the other hand, patents make public details about innovations, and the patenting process, in particular the defence of patents, is extremely costly and time consuming. In the United States, for example, attempts by Canadian firms to take American firms to court are invariably opposed by countersuits based on anti-trust legislation. Clearly, for the small and medium-sized firms that characterize the Canadian industry to oppose rival firms in foreign courts is a high-risk venture. (Forest-product manufacturing firms also had mixed views regarding patents.)

The fact that the innovations generated by the in-house R&D programs of forest-product firms (Table 3.1) are mainly restricted to pulping processes and those generated by the in-house efforts of equipment suppliers (Table 3.3) to wood-harvesting and processing products is unfortunate. These separate interests, which are deeply ingrained and which will continue in the near future, contribute to the industries' emphasis on exporting bulk commodities and their failure to develop highly processed wood products. More overlap in research interests would lead to closer technological liaisons between forest-product manufacturing firms and equipment suppliers in Canada.

The Opco Process: A Case Study of In-House Technological Innovation

The story of the development of Opco pulp serves as a useful case study of in-house technological development in the Canadian forest-product industries. Opco pulp was developed by the Ontario Paper Co. and is a type of chemithermomechanical pulp (CTMP), produced by cooking mechanical pulp, preferably TMP, with sodium sulphite, whereas conventional CTMP is produced by cooking chips.⁵ The approximate 10-year chronology of the development of Opco Pulp can be summarized as follows:

- 1. In the early 1970s Ontario Paper began R&D on the importance of wet web properties to a pulp's performance on the paper-making machine.
- 2. In 1977, stimulated by new Quebec government pollution regulations, the company stepped up research on a replacement for the high-yield suphite pulp that had been introduced in 1970.
- 3. By September 1977 laboratory work led to the discovery of a pulp with improved wet web properties and a 90 per cent yield, which would look after the pollution problem.
- 4. Trials were then arranged on commercial (100 tonne) scale equipment at the Kaipola Mill of United Paper Mills in Finland because in Canada such large-scale experiments were impossible. The pulp had to be shipped to another Finnish mill for reaction in a Pandia Digester and then shipped back to Kaipola to be run on a paper-making machine. Pressroom trials in Finland and North America indicated that the paper performed better than standard newsprint on the press, with less linting, and print quality was better.
- 5. In fall 1980 an agreement was reached with Hymac of Montreal and United Paper Mills of Finland to build a 50-tonne reactor and pilot plant at Kaipola to produce Opco pulp on a continuous basis. A pilot plant was necessary to obtain better data on the pulp's performance and to prepare detailed designs of equipment. Six paper-making machine trials of one shift each were performed and subsequent pressroom performance confirmed earlier tests.

- 6. In late 1981 Ontario Paper installed a 225-tonne Opco plant at its Baie Comeau mill at a cost of \$28 million. Twenty-three contracts were awarded and Hymac was the main equipment supplier.
- 7. The first Opco plant opened in October 1983.
- 8. The equipment made by Hymac and United Paper is for sale to other companies, and royalties accrue to Ontario Pulp and Paper. United Paper has exclusive rights in the Soviet Union.

This case study illustrates the length of time required to develop major technology in the forest-product industries, the cooperation required between forest-product firms and equipment manufacturers, the close ties between R&D and investment planning, the importance of both the "push" of science and the "pull" of demand, and the advantages to forest-product firms of access to even a small, high quality in-house R&D group. The research done in the early 1970s allowed the R&D group to respond quickly when the firm decided in 1977 to develop a new pulping process in response to the Quebec government's environmental legislation. If the firm had had to turn to Paprican or some other group, timing, administrative, and technology transfer problems would have been more likely. An external group would have faced two immediate disadvantages: first, they would have had to familiarize themselves with the firm's situation and, second, they would have had to start from scratch in terms of R&D. By using its own resources Ontario Paper enhanced its ability to generate new technology and its potential for royalty payments.

The case study also reveals the importance of, and some of the problems facing, pilot plant studies and commercial trials in forestproduct R&D. The role of the Finnish firms illustrates the greater interest in innovations and the closer links between forest-product firms and equipment suppliers in Scandinavia. In this case, Finland will acquire many of the benefits of the Canadian technology. To the extent that Finland's United Paper can market and further develop the equipment it will compete directly with Canada's Hymac. The failure to develop Canadian technology fully in Canada is not uncommon.

Paprican as Technology Supplier

Paprican is on the leading edge of a variety of pulp and paper technologies. Historically it has emphasized basic and applied research; however, within the last two decades it has become increasingly involved with technology transfer. Indeed, as of February 1984 Paprican reported that it had developed 41 products and processes of which 22 have been "successfully" commercialized, five have failed, and 14 were still open (Table 3.4). Their earliest and best known project was the Papriformer, a pioneering effort in the evolution of twin-wire technology.

The Papriformer, one of the institute's most important innovations, developed from research conducted in the 1950s into the problem of short (paper machine) wire life due to increased machine speeds. A Paprican task force identified various causes of short wire life such as drag load, grit, and speed. This study led to the centricleaner (to remove grit), the development of contemporary drainage technology of suction boxes and non-metallic wires, and to an aware-

23	February 1984						
		Initiati	on				
		Science		Commercialization Status			
Pro	oject	Push	Pull	Unsucc.	Open	Succ.	
1.	Atomic suspension						
	technique		x	x			
2.	Activated carbon						
	products	x		x			
3.	Automat. gas chromatic						
	monitor	x	x			х	
4.	Wet gas scrubber	x	x			х	
5.	Dry gas scrubber	x	х		x		
6.	Papribleach	x		x			
7.	Paprizone	x			x		
8.	Chlorine monoxide	x		x			
9.	Papritection		x			x	
10.	Polyethyleneoxide		x			x	
11.	Pitch count technique		x			x	
12.	Anthraquinone	x			x		
13.	Papriformer	x				x	
14.	Papridryer		x		x		
15.	Wire life		x			x	
16.	Steam showers		x			х	
17.	Temperature gradient						
	calendering	x			x		
18.	Press caustic extraction	x				х	
19.	Refiner control	x	x			х	
20.	Simulation models		x			x	
21.	Chip debarking		x		x		
22.	Chip pipeline		x	X			

Table 3.4: Products and Processes Developed by Paprican to 23 February 1984

ness "that the Fourdrinier paper machine was approaching the limits of its productive capacity and product quality."⁶ Researchers identified the characteristics of an ideal web as a sheet with similar printing characterics on both sides, uniform fibre distribution, and with greater smoothness and quality than previous webs. They sought to make a forming device that was capable of producing such a web in a range of commercial base weights, that required less space, was easier to operate, and produced more paper.

By 1959 they had built a crude Mark I forming unit and demonstrated that a very compact former could operate at the speed of commercial newsprint machines. Subsequently, their Mark II (the "demon"), incorporating major improvements in drainage technology and instrumentation, was financed and built by the Dominion Engineering Works (DEW) of Montreal. They built an initial prototype

Initiation	
Science Commercializ	zation Status
Project Push Pull Unsucc. Op	en Succ.
23. Shear counter x x	X
24. Recovery furnace x x x	(
25. Plate clash detector x	x
26. Starting torque transients x	x
27. 100% thermomechanical	
pulp newsprint x	х
28. Digiburst x	x
29. Lumen loading x x	
30. Curl set x x	
31. Electrochemical pump	
protection x x	
32. Data acquisition system x x	
33. Wood waste in lime kiln x x	
34. Hog fuel drying x x	
35. Tall oil production x	x
36. Kappa oil production x	x
37. Length and slenderness	
factors x	x
38. H (energy) Factor x	x
39. Printing smoothness	A
tester x	x
40. Dirt counter x	x
41. Va-Purge Process x x	~

 Table 3.4: Products and Processes Developed by Paprican to

 23 February 1984 (Continued)

Source: J. Merca, Director, Patents, Licences and Allied Industry Division, Paprican, personal communication, 13 June 1985.

in 1959, and a full-scale experimental prototype in 1965. Experience with this prototype led to the design, installation, and operation of commercial units. The first was installed at Bramptonville by Kruger Pulp and Paper. The machine, which was licensed by DEW, took approximately 15 years to develop and in 1975 Paprican was the first recipient of the Governor General's prize for engineering design in the industrial equipment category. By 1976, 13 Papriformers, including six in Canada, were in operation or were being built. Unfortunately, the Papriformer was not subsequently technically developed as effectively as rival twin-forming technology, and in 1984, to obtain better access to the Canadian markets for its own machines, Valmet of Finland acquired DEW.

Cable 3.5: Stages in the Development of Selected Technologies by Paprican							
Innovation	Date of Invention (Stage 4)	Date of Commercial Use (Stage 6)	Interval (Years) to Reach (Stage 6)	Stage Reached			
Papriformer	1963	1972	9	(7)			
Papridryer	1964	Open		(5)			
Papribleach	1967	Open		(5)			
Gas scrubbing	1970	1975	5	(7)			
Press alkaline extraction	1972	Open		(5)			
Chip debarking	1973	Open	_	(4)			
Papritection	1977	1980	3	(7)			
Plate clash detector	1978	1980	2	(6)			
Lumen loading	1980	Open	_	(3)			
Additives for retention & pitch control in paper manufacturing	1980	1981-82	_	(4) (6-7)			
Method of producing lime in							
a rotary kiln	1981	Open		(5)			
Curl setting	1981	Open		(4)			
Electrochemical pump		1					
protection	1983	Open	_	(5)			
Digiburst	1978	1980	2	(7)			
Data acquisition system	1982	probably 1984	(2)	(5)			

Source: J. Merca, Director, Patents, Licences and Allied Industry Division, Paprican, personal communication, 13 June 1985.

Note: Stage 1 is the scientific suggestion, discovery, observation or recognition of member company need; Stage 2 is the development of theory or design concept; Stage 3 is lab verification of theory or design; Stage 4 is lab demonstration of application (invention); Stage 5 is the field trial or full-scale trial (technical success); Stage 6 is commercial introduction; and Stage 7 is widespread adoption (commercial success).

Table 3.5 shows the stages of development of selected innovations, including the Papriformer. The period between invention (stage 4) and commercial introduction (stage 6) varies from two to, in the case of the Papriformer, nine years. Given the stages in Table 3.5, the length of the R&D process prior to invention (stage 4) is as long as, if not longer than, the post-invention stages. In the case of Papritection, which has enjoyed considerable commercial success, initial research began in 1974, three years before the first prototype was built and six years before the first commercial installation. In fact, Papritection provides an interesting case study of how Paprican seeks to develop and transfer technology (Table 3.6).

Stage	Date (approx.)	Comment
Applied research	1974-77	Three scientists in the corrosion and materials engineering section of Paprican conduct research into the high cost of corrosion
Development	Dec. 77	First R&D prototype in chlorination stage washer
Development	Feb. 79	First R&D prototype in chlorine dioxide stage washer
Development	June 79	Licensing agreement with CSCL of Toronto
Development	Nov. 79	Paprican reports prototype success to Canadian member companies
Technology transfer	June 80	Commercial use by Canadian licensee Patents filed
Technology transfer	June 81	First patent issues
Technology transfer	June 83	Sub-licensing agreement with Swedish
Technology transfer	1985	Licensing negotiations with Japanese company

Table 3.6:	Papritection: Summary of Development
<u></u>	

Jnits Sold



Source: J. Merca, Director, Patents, Licences and Allied Industry Division, Paprican, personal communication, 13 June 1985.

Papritection was developed as follows:

- 1. In 1974 the concept of Papritection originated within the corrosion and materials engineering section of Paprican.
- 2. In December 1977 the first prototype was built.
- 3. In February 1979 the second prototype was built.
- 4. In June 1980 a licensing agreement was signed with Corrosion Service Co. Ltd. (CSCL) of Toronto, which provided for a sliding scale or royalties with CSCL paying 100 per cent in the first year and 50 per cent in the fifth year. This scale was introduced to encourage the equipment supplier to develop the technology.
- 5. In June 1980 Papritection was built on a commercial scale. By 1985, 64 had been sold (31 in Canada); revenue totalled \$3.6 million and royalties amounted to \$585 000. In June 1983 a licensing agreement was signed with a Swedish company and another licence is being negotiated with a Japanese company.
- 6. The licence with CSCL was assessed in June 1985, after a five-year period, and the agreement was renewed.

The R&D costs probably amounted to \$1.4 million, but the return on Papritection must be substantial. According to Paprican, it would not have been possible for a company such as MacMillan Bloedel to have developed Papritection.

Feric as Technological Catalyst

In seeking to stimulate technological innovation in Canadian woodharvesting operations Feric has rarely become involved in applied research and the building of prototypes. Rather the institute has gone out to wood-harvesting sites and identified technological needs. Then by suggestion, collaboration, and sometimes financial support Feric has sought to stimulate innovation in wood-harvesting both directly, and indirectly through product development by Canadian-based logging and silvicultural equipment manufacturers. A good example of Feric's role as a "technological catalyst" is provided by the development and application of high flotation ("wide") tires.⁷

Wide tires had apparently been tried in the Canadian woods in the early 1960s but were discarded because they were too heavy, sluggish, and expensive. The potential advantages of using wide tires on logging machines, however, aroused renewed interest during the 1970s as a result of environmental and silvicultural concerns, an interest in reducing fuel consumption, and improvement in techniques of, and materials for, manufacturing wide tires that were light, thin-walled but difficult to puncture. The events that led to commercial development of high flotation tires in Canada are as follows:

- 1. In 1977 Feric investigated a novel off-highway carrier that had distinctive drive and suspension characteristics and required large, high flotation tires. Feric decided the vehicle was unsuitable and that a more effective strategy would be to first develop a high flotation tire and then develop an off-highway carrier.
- 2. In 1979 Feric organized a worldwide search for a wide tire that would be adaptable to existing skidders. Various criteria, such as tire width, flexibility, resistance, and design, were specified. Although established forest-machinery tire manufacturers remained sceptical, Feric eventually discovered a manufacturer in Texas, Rolligon, that made wide tires for geodetic purposes. Feric judged the tires had potential, but Rolligon initially expressed little interest in modifying the tires for logging purposes.
- 3. Notwithstanding the lack of enthusiasm shown by industry, Feric purchased five (modified) Rolligon tires in January 1980 to promote the development of wide tires for forestry purposes.
- 4. In early 1980 Feric mounted the Rolligon tires on a John Deere skidder, which was the only existing model on which the tires could be fitted easily. Field trials were conducted on the limits of the Spruce Falls Power and Paper Co. in the clay belt of northern Ontario. In return for the chance to be the first manufacturer, the American-owned John Deere lent Feric a machine and guaranteed fast service and a supply of spare parts.
- 5. The results of the first field tests, and of subsequent tests in September and November 1980, revealed spectacular productivity increases and minimal ground disturbance.
- 6. In February 1981 Feric, encouraged by the performance tests, organized a meeting between equipment manufacturers, tire manufacturers, and logging development engineers to stimulate the commercial production and diffusion of wide-tire technology.

Further tests were conducted in 1981 during which time United Tire and then Firestone introduced their own versions of wide tires, which, contrary to Feric's advice, were modifications of their existing aggressive-tread tires. These tires did not perform well and they were discarded.

- 7. During several trials organized by Feric in 1982 and 1983, United, Firestone, and Goodyear successfully introduced non-aggressive, flexible wide tires that would not break through the forest mat in Ontario conditions. In addition, first Timberjack and then other equipment manufacturers effectively modified their skidders to permit use of wide tires. These trials also extended the evaluation of wide tires in various site conditions other than the soft clays of northern Ontario. Feric further facilitated diffusion by loaning wide tires to individual firms to conduct their own testing while some firms, for example, MacMillan Bloedel, purchased their own.
- 8. By 1983, 100 units had been sold in Canada, wide tires suitable for conditions in the southern United States had been developed by United, and John Deere had established an export market in South Africa.

Thus in four years of testing and evaluation Feric contributed much to the diffusion of a new breed of wide flexible high flotation tires that significantly improved skidder performance in a variety of applications. Depending upon site conditions, the new tires offer productivity increases, fuel savings, and reductions in soil disturbance as well as improved operator ergonomics.8 As Feric's most notable success, the development of wide tires reveals much about Feric's approach to innovation. In particular, the case study illustrates that Feric's activities are strongly developmental and concerned with adapting technology, regardless of its origins, to suit specific site conditions in Canada. In its role as catalyst, in the case of wide tires, Feric identified a specific technological need and then identified plausible solutions and brought together initially reluctant partners from industry in trials that it organized and evaluated. Moreover, Feric's intimate knowledge of Canadian conditions and its engineering design skills enabled it to specify requirements and to evaluate prototypes from industry in a constructive way.

Feric is essentially North American in outlook and does not favour Canadian firms over American-based firms and organizations or American subsidiaries in Canada. Within Canada, Feric does not seek to promote R&D; it frequently supports small entrepreneurial companies that do little or no formal R&D. It may be argued, therefore, that Feric bolsters a fragmented and technologically dependent Canadian equipment industry.

Forintek as Technological Bridge

Forintek's technological role in the forest-product R&D system of Canada is less clear, in part, because of its recent origins and, in part, because its policy thrusts are diverse. Forintek sees itself as a "technological bridge" between the forest, which is rapidly changing from a wild to a cultivated resource, and wood-processing companies, which are facing rapid technological change. These very changes are one reason why Forintek's technological policies are so varied, ranging from quality control, to the adoption and adaptation of "best practice" technology from foreign countries (as Feric does), to undertaking R&D projects of its own (as Paprican does). Because of its short history as a cooperative laboratory, and its mandate to serve industry, Forintek's short-term and developmental activities have received the most attention.

To improve quality control, Forintek introduced a Sawmill Improvement Programme (SIP) to identify problems and suggest improvements in mills. The potential benefits of SIP should not be underestimated. A similar program in the United States saved at least 12.8 million cubic metres of lumber in 10 years through more efficient operations.⁹ More recently, Forintek introduced a computerized lumber size program "designed to identify the smallest possible rough, green size of lumber required to produce the final dry, dressed market size product."¹⁰ It will help improve lumber recovery and reduce maintenance costs.

Forintek urges wherever possible the use of already developed foreign technology, for example Stellite tips in Canadian sawmills. Stellite tipping was developed by the French National Research Institute for Forest Products and is used widely in tropical hardwood sawmills where most of the tipping is still done manually.¹¹ In recent years sawmills in Europe, the United States and, finally, Canada have begun to realize the benefits of Stellite tipping in terms of accuracy, smoothness, narrow kerf, fewer repairs, and lower cost.¹² In Canada, this has been due to the efforts of Forintek. Following extensive experimentation by Forintek and Chaston Industrial Saw of New Westminster, initially using semi-automatic machines from Germany and Switzerland and Malaysian labour (with previous experience in tipping), Stellite tipping was introduced into a British Columbia sawmill in 1982. With the development of German, Italian, and French fully automatic machines, and its success elsewhere, the diffusion of Stellite tipping in Canada is now likely to be rapid.

The Detenso saw blade is another foreign (German) technology that Forintek has discovered for Canada and helped adapt to local conditions.¹³

Forintek also does its own long-term applied R&D. In late 1984, for example, Forintek launched a three-year study of lumber drying that involved research in thermodynamics, the fluid dynamics of air, and wood science.¹⁴ Forintek's most fundamental R&D program, however, concerns biotechnology. Its Ottawa-based biotechnology group is focusing on producing sugars from wood residues with a view to producing an economical glucose that can then be converted into chemicals. The group can draw on a collection of more than 3000 fungi, yeasts, and bacteria dating from 1921.¹⁵ Although there is not now a significant market for wood products in the biotechnology area, Forintek may provide industry with the necessary expertise when and if market opportunities do arise.

Technology Diffusion and the Direction of Change

This chapter has provided some examples of how technology is used to generate and commercialize new products and processes within the Canadian forest-product industries. It has not identified the factors that shape the diffusion of an innovation that has been commercialized. Other studies of the Canadian situation¹⁶ have revealed the diffusion process to be complex and difficult to explain in purely statistical terms. The spread of a new product or process can only be analysed within specific organizational and investment contexts that are usually best considered on an international scale. Moreover, in the forest-product industries once a new product or process is commercialized, its subsequent growth, competitiveness, and application in other regions depends largely on successive research inputs.¹⁷

Although the pace of technological change is difficult to predict, incremental innovations will continue and these changes will exert a significant impact on productivity and market performance. Tillman argues that there are many emerging technologies within the forest-product industry that will lead to improvements in the production of pulp, lumber, panel products, fuels, electricity, dietetic foods, and so on.¹⁸ It is the basic and applied R&D that is being done now and that has already been completed that will provide the basis for major innovations in 5, 10, or 20 years' time. These firms doing this research, or with the capability to grasp its importance, will be in the best position to commercialize it.

With respect to the direction of technical change, four leadingedge technologies — information technology, biotechnology, intelligent machines, and materials technology — will exert a profound influence on the forest-product industries in the future. Information technology, in the form of microelectronics has already been extensively applied to forest-product operations and these applications will increase, both individual processes and mill-wide automation plans.¹⁹ There is also a rapidly growing awareness of the implications of developments in biotechnology, robotics, and materials technology for the forest-product industry.²⁰

In the immediate future, innovations will continue in the traditional technologies. In the pulp and lumber industries, where innovations are badly needed to counter significant cost disadvantages, both Tillman and Hopgood have reviewed a large number of recent and possible innovations.²¹ In chemical pulping alone, Tillman discussed improvements with respect to digester processes, causticizing systems, recovery boilers, and pulping systems.22 Tillman is particularly optimistic about chemithermomechanical pulping (CTMP), which offers strength, yield, and energy cost advantages, and capital costs low enough to make small-scale mills viable.23 Alternative potential pulping systems also noted are oxygen delignification, the Masonite process, soda-amine systems, biological pulping (in the long run), and organosolv pulping.24 Organosolv and (borate-based) autocausticizing pulping are two of the most highly touted technologies that represent distinct departures from conventional systems.²⁵ The latter may permit the elimination of the recausticizing system in kraft pulp mills at a capital cost saving of about (U.S.) \$26.4 million as well as some operating cost savings. Organosolv pulping offers a small-scale alternative, with a low capital cost. Although Tillman doubts organosolv pulping will compete with the CTMP process in usual applications, he feels it may find uses in the production of chemicals or foodstuffs from wood

Turning to lumber production, Tillman identified the advanced control sawmill as a possibility that is likely to be widely adapted.²⁶ He also listed technologies that would use wood to produce energy, chemical, and related products, observing that these uses of wood have greater growth potentials than the traditional ones.²⁷

In summary, although the forest-product industries are mature, there is no shortage of technological opportunities.²⁸ Many consider that the diffusion of forest-product technology has not been fast enough and that Canada's ability to generate and benefit from technology has declined.

Chapter 4

Technological Capability and Technological Liaisons: An Assessment

The lack of in-house R&D by forest-product firms and by equipment manufacturers is the weakest link in the Canadian industries' technological capability. Technological capability refers to the industries' ability to solve scientific and technological problems and to follow, assess, and exploit scientific and technological developments.¹ Although government and industry decision makers have recognized the need for more R&D efforts by industry, the advantages of *in-house* R&D for individual firms and for the system as a whole are not fully appreciated. Also, underfunding of in-house R&D arises in part from the high level of foreign ownership. The rapid growth of "cooperative" laboratories in Canada cannot fully substitute for in-house R&D by forest-product firms and does not compensate at all for the low level of in-house R&D by equipment suppliers.

R&D in the Forestry Sector in Canada and the United States circa 1977

In Canada and the United States R&D is done by the laboratories of forest-product manufacturers, the "cooperative" laboratories they sponsor, and the laboratories of the United States and Canadian governments. Table 4.1 shows the percentage of R&D professionals employed by industry and the federal governments in Canada and the United States in relation to population, forest-products employment, and the size of the wood harvest. The data apply to the situation prior to the recent rapid growth of cooperative laboratories in Canada.²

According to directories and fieldwork for an earlier study,³ there were 5485 professionals in the two countries employed in forestproduct R&D laboratories that were operated either by forestproduct firms independently or collectively as cooperative laboratories or by the federal governments. The R&D efforts of forest-product firms, however, account for 68 per cent of the total. Industry R&D is overwhelmingly concentrated in the United States; 93 per cent of industry's R&D professionals are employed there. Canadian industry's share of professional R&D employment is a modest 7 per cent, about 260 professionals compared to 440 working for the federal government. Forest-product R&D is concentrated in regions that were once (before 1940) important for pulp and paper production and that are now headquarters for many of today's forest-product giants (see chapter 2). Canada's federal government employs proportionately more professionals than the United States federal government, and the employees are more dispersed than their counterparts who work for private industry.

Table 4.1: Share (%) of Forest Sector Professional R&D Employment in Canada and the United States in Relation to their Share (%) of Population, Forest-Product Employment, and the Wood Harvest

	Professio	nal R&D Emp	oloyment		Total Employmen in Forest- Product	Size of Wood
	Industry	Fed. Govt.	Totala	Population	Industries	Harvest
U.S. Canada	93.2 7.0	69.0 31.0	84.9 15.2	90.6 9.6	85.8 14.1	76.6 23.4
Total	3719	1 419	5 485	224.8 million	1.3 million	519 million cubic metres

Source: R. Hayter, "The evolution and structure of the Canadian forest product sector: an assessment of the role of foreign ownership and control," *Fennia*, 163 (1985): 447.

Note: The population figures are based on 1970 U.S. totals and 1971 Canadian totals, the forest-product industries' employment is for 1972, and the wood-harvest data for 1970. The R&D employment reflects the situation in circa 1977.

^a Although industry-sponsored coop employment is not indicated separately it is included in the total.

The majority of large forest-product firms consider R&D a desirable investment. Approximately 70 per cent of the professional jobs in industry R&D are controlled by the 20 North American-based pulp and paper producers with sales in excess of \$650 million in 1976.⁴ The four largest R&D employers, all American-controlled multinationals, accounted for 37 per cent of the total and the four Canadiancontrolled firms in this group (also multinationals) accounted for less than 5 per cent. A few large forest-product firms do not invest in R&D, however: Louisiana-Pacific, the largest forest-product corporation in the world, is an example.

Table 4.2 provides measurements of the weakness of industrial R&D in the Canadian forest-product industries around 1977 in a North American context: the measurements are dubbed "location quotients" and an explanation of how they are derived is provided in a note to the table. Calculated on the basis of population, of forestproduct employment, or of the wood harvest, the location quotients for in-house professional employment in R&D by forest-product firms are less than one for Canada as a whole. (A measure of one implies no weakness in representation.) The results are similar when viewed on a regional basis except for British Columbia with population as the criterion. Industry's location quotient for the wood harvest indicates the private sector should more than triple its R&D professional employees to maintain a representative presence in North America. However, the table shows that federal government R&D is relatively much stronger in Canada than in the United States. In Canada, in-house R&D by industry is extraordinarily meagre compared to that in the United States.

ze of Harvest
0.3
1.3
0.6
2

Table 4.2:	Canada's	Share of	Forest-Produc	t R&D in	North	America:
Location Q	Quotients					

Source: R. Hayter, "The evolution and structure of the Canadian forest product sector: an assessment of the role of foreign ownership and control," *Fennia*, 163 (1985): 447.

Note: Location quotients are derived by dividing the Canadian share of professional R&D employment in the United States and Canada by the Canadian share of the three selected criteria in the United States and Canada.

In fact, in the mid-1970s industry efforts in forest-product R&D in Canada were relatively smaller than in Sweden, Finland, Japan, or the United States.⁵ In 1975, for example, Sweden accounted for 5.46 per cent of world pulp and paper production but 8.3 per cent of OECD-based forest-product R&D expenditure; Finland accounted for 3.88 per cent of production and 4.14 per cent of R&D expenditure; Japan for 9.40 per cent of production and 14.0 per cent of R&D expenditure; and the United States for 34.50 per cent of production and 55.30 per cent of R&D expenditure. Canada with 10.50 per cent of global pulp and paper production accounted for just 5.91 per cent of OECD-based forest-product R&D expenditure.⁶

Have Canada's forest-product R&D efforts, particularly by industry, improved relative to the United States and other OECD countries since the mid-1970s? Although many relevant data are lacking, the following facts indicate they have not. As noted on page 49, the steady decline in in-house R&D by Canadian forest-product firms that occurred during the 1970s levelled off between 1981 and 1985.

In the United States, there have been cutbacks over the past five years. At the three American laboratories where this author conducted interviews the peak 1979 R&D employment levels had fallen substantially by 1985: in 1985 alone one firm cut its R&D staff by 80 per cent — although this drastic and unexpected cutback appeared to have been strongly influenced by the threat of a hostile takeover. Nevertheless, annual data on the leading R&D performers in the United States also reveal that during the 1980s several American firms have recorded significant R&D increases.⁷

In terms of budgets and employment levels American in-house efforts remain proportionately larger than those in Canada. In 1985, for example, Weyerhaeuser employed 500 R&D professionals at its Tacoma complex, about double the number employed in-house by all Canadian firms and yet Weyerhaeuser's \$44.1 million budget was only about 1.5 times larger than the combined budgets of Canadian companies. And in the same year seven American forest-product giants spent \$306.5 million on R&D including \$109.4 million by Kimberly-Clark.⁸ Available anecdotal evidence from newspapers, trade journals, and personal communications all point to the continuing strong commitment of Finnish and Swedish wood-product firms to R&D.

In-House R&D by Equipment Suppliers: Another Weak Link?

The level of R&D among Canadian-based equipment suppliers is also low. The machinery manufacturing industry is generally regarded as medium or high tech, but only a few Canadian forest-product equipment suppliers have ongoing R&D programs, and these are not large by international standards. The amount invested in R&D by the Canadian firms is woefully low as a percentage of sales. Firms such as Beloit (United States), Valmet (Finland), Escher Wyss and Voith (Germany), and Kamyr (Sweden) are international in scope and in their home countries operate laboratories that are much bigger than the largest in Canada.

Data do not exist that would allow assessment of the international R&D performance of Canada's forest-product equipment industry in terms of employment and budget levels. Fortunately, Hanel provides a comprehensive analysis of the corporate and international origins of

forest-product equipment patents, which are conventionally regarded as a useful indicator of R&D output.⁹ According to Hanel, patent counts between 1978 and 1980 reveal Canadian inventors to be most competitive in forestry machinery but progressively less so with respect to wood processing, pulp and paper, and paper-converting technology.¹⁰ Canada accounted for 28.9 per cent of the 135 patents issued between 1978 and 1980 with respect to forestry equipment, for example, but only 8.9 per cent of the 395 pulp and paper patents and 5.8 per cent of the 208 paper-converting patents during the same period. The same relative differences, only less marked, appear in a 10 per cent sample of patents issued between 1950 and 1975.¹¹ Hanel goes on to note that Canada's traditional strengths in forestry equipment are being reduced by stiff Swedish competition, and (recent) pulp and paper machinery patents are overwhelmingly concentrated in the hands of American, Swedish, and Finnish firms.¹²

Most R&D efforts in Canada by equipment suppliers for the forestproduct industries are in logging and wood processing. The high level of demand for technology in these industries, the high proportion of entrepreneurs, and the distinctive nature of the Canadian forest environment contribute toward Canadian excellence. Even here, however, foreign firms are making inroads. In particular, in Canadian woods and wood-processing operations, indigenous technology is rapidly being supplanted by innovations from Austria, Finland, Germany, Italy, Switzerland, Sweden, and Japan, as well as the United States. Stellite tip manufacturing equipment and Detenso blades are two examples (see chapter 3). Another is the "spider-like" machines developed in Switzerland and Austria for silvicultural site preparation in extremely steep terrain.¹³ Italian manufacturers also recently started to assess the Canadian market for a variety of wood-processing machinery.¹⁴

With respect to highly processed products — pulping equipment, paper machinery, and electronic equipment for the forest industry — Canadian technological capabilities are weak. Among surveyed firms only two, both Canadian-owned, are reasonably strong R&D performers in these fields. These products can be standardized in a manner that facilitates global sales. Even if the efforts of two companies not included in the sample are recognized, Canadian in-house R&D levels in the technologically most dynamic aspects of forestproduct manufacturing are limited.

Despite the activities of the Foreign Investment Review Agency (FIRA), foreign firms have been permitted to acquire Canadian forestproduct suppliers with little restriction. And high levels of foreign ownership mean less Canadian-based R&D. In 14 of the 18 foreignowned firms in the sample, R&D in Canada is almost non-existent: 11 of the 14 firms rely "very strongly" on parent company R&D, and two others "moderately strongly." The four that do maintain independent R&D programs are, in each case, the parent company's only manufacturing base for forest-product equipment. These companies do R&D that is "strongly different" from that of their parent company. In general, however, international equipment manufacturing companies centralize their R&D in their home countries. Valmet's decision to phase out the R&D group of Dominion Engineering Works of Montreal, following the acquisition of the latter in 1984, is typical.

Remaining Canadian firms are small or medium-sized and confined to increasingly narrow market segments, and these circumstances do not favour sustained R&D programs. Therefore within Canada domestic and foreign-owned firms show little difference in terms of level of R&D.15 As a Finnish observer has recently noted, despite high levels of demand in Canada, there is not one important Canadian-owned multinational company in the forest-product equipment business.¹⁶ Nor, to the author's knowledge, has any Canadian company established a branch outside North America. In contrast, firms such as Beloit, Voith, and Valmet have built manufacturing facilities in several countries, including low-wage developing countries. In Canada, foreign subsidiaries typically do not have the mandate and locally owned firms do not have the size to pursue similar strategies. There is a danger that Canada's equipment manufacturing base will be gradually lost to developing countries as R&D becomes concentrated in other industrialized countries.

Given that so many equipment suppliers are foreign subsidiaries it is not surprising that the 37 surveyed firms do not issue many patents or licences. Thus 30 reported not licensing their technology to others. Significantly, 18 firms did manufacture the products of foreign firms under licence. This represents a net inflow of licences into Canada and confirms our technological dependency. The companies that issued the licences were based in Scandinavia, Japan, America, Italy, and, in a few recent cases of cross-licensing, Finland. Some examples of licensing arrangements are

- leading R&D-oriented firms in wood processing, electronics, and logging have recently licensed Swedish products.
- A Finnish firm, Raute took over Durand of New Westminster and obtained a licence to manufacture the latter's rotary clipper and Durand now manufactures several of Raute's products.
- C.A.E. of Vancouver has also entered into a joint venture with Ahlstrom of Finland; for C.A.E. the deal meant a licence to manufacture Ahlstrom's edger optimizer.

Foreign-Ownership and In-House R&D

The low level of in-house forest-product R&D in Canada and the relative strength of efforts by the federal government, at least until 1979, both stem from American ownership and control of much of Canada's forest sector.¹⁷ Overwhelmingly, American forest-product companies operating in Canada have centralized their R&D investments in the United States. On occasion this has involved closing down large Canadian facilities.¹⁸ In only three cases have American forest-product subsidiaries invested in important R&D facilities in Canada in recent decades. In all instances the circumstances were unusual.¹⁹

In Canada, foreign-owned subsidiaries usually rely on parent companies for R&D. This seriously erodes indigenous technological capability in these industries. Although subsidiaries have ready access to their parent's technological expertise, such intracorporate ties, according to the Gray Report,²⁰ have left subsidiaries technologically "truncated" and have contributed substantially to the low level of industrial R&D in the Canadian forest-product industries. Similarly, the numerous joint ventures that involve foreign partners typically enjoy access to the foreign partner's company laboratory and have no mandate to undertake their own R&D.

There has been some controversy regarding the Gray Report's claim of "truncation" in the forest-product sector. Pearse and Kates et al. found no differences in the R&D performances of foreign subsidiaries and Canadian firms in the B.C. and Ontario forest industries, which led them to believe that being a foreign subsidiary does not erode a firm's technological capability per se.²¹ However, the methods employed in their studies are open to question. Pearse did not reveal any details about "the nature of his investigations" and Kates et al. only sampled five firms. The studies are also too narrowly conceived to assess properly the effect of foreign-ownership on a firm's technological capability; they ignored international corporate affiliations and the aggregate impacts of foreign investment on industry structure as a whole.²²

One way in which Canada's forest-product and related firms are influenced by foreign-ownership is in their technology strategies. Firms with a "dependent"²³ technology strategy make no attempt to initiate technical or product change except at the specific request of a customer, or parent, who also provides the expertise to implement the requested changes. An "imitative" technology strategy means a firm seeks to copy the technological leaders. Predominantly, Canada's forest-product firms and equipment suppliers are committed to one of
these "adaptive" technological strategies and lack an in-house R&D organization. Thus Canadian equipment supply firms have not provided new technology to Canadian forest-product firms as quickly or as effectively as their counterparts in other countries.

Foreign-ownership of much of the industry also leads to major gaps in the indigenous R&D that is performed by the more technologically aggressive companies. Thus, the emphases on new pulping processes by forest-product firms and on innovations in woodprocessing equipment by equipment manufacturers, both attempts to develop "customized" technology for distinctly Canadian environmental conditions, mainly support Canada's role as global supplier of bulk forest-product commodities. The use of R&D to develop alternative products for new export markets has been underemphasized.

Adaptive technological strategies are expensive for Canada. Canada's forest-product industries, like the economy as a whole, are substantial net importers of invisibles. For example, net non-merchandise balance-of-payments losses, which include payments for R&D and other corporate services, have long been substantial.²⁴ This is a deplorable situation for industries in which Canada has had a comparative advantage.

Moreover, Canada's failure to fully exploit export potentials, including invisibles, in these industries stems from a low level of R&D. Hanel's detailed study of Canadian forest-product equipment manufacturers statistically demonstrates that, for the industry as a whole and for individual firms, a technological edge improves export performance.²⁵ Hanel also shows that, during 1975-80, the more specialized forest-product equipment manufacturers enjoyed greater export success than the more diversified ones and that those firms that increased R&D and degree of specialization in this period improved their export performance more than other firms.²⁶ Admittedly, indigenous R&D is not the only determinant of exports; Canadian exports of pulp and paper machinery are generated both by Canadian firms with in-house R&D and by subsidiaries without R&D. But the latter's exports are typically controlled by American and European parents that do conduct R&D and that limit Canadian exports to the U.S.

The low levels of in-house R&D that stem from foreign-ownership also result in fewer job opportunities not only for science and engineering graduates but also for production and related business personnel.

Technological Liaisons: Forest-Product Firms and Equipment Manufacturers

Although forest-product firms are the principal customers of equipment suppliers, in Canada there is no systematic cooperation between forest-product firms and equipment suppliers in the development and exploitation of technology. (Such cooperation exists in Scandinavia.) Technological liaisons between the in-house R&D groups of forest-product firms and of equipment suppliers are sporadic. R&D by equipment suppliers generally leads to the development of prototypes that are tested in the facilities of a forest-product firm (which may obtain lower prices for its willingness to be a guinea pig), by its in-house R&D group, where one exists. Similarly, forestproduct firms that develop new technology normally seek a close working relationship with an equipment supplier.

In part, the lack of close technological liaisons between the two groups reflects their widely separate research interests and, in part, their competitive arm's-length relationships. Equipment suppliers are rarely willing to invest in R&D for a new product without receiving positive signals from customers. For their part, forest-product firms are rarely willing to underwrite the costs and uncertainties of longterm product development by suppliers. On the whole, R&D managers of forest-product firms consider foreign equipment suppliers to be more innovative than Canadian-based equipment suppliers (Table 4.3). Similarly many equipment suppliers consider Canadian forestproduct firms, with exceptions, to be conservative toward innovation. Many suppliers expressed concern that their customers were not willing to pay for higher quality, technologically more sophisticated products but constantly bargain to reduce costs. Foreign-based equipment suppliers have long enjoyed easy access to the Canadian market, because forest-product firms have lobbied for and won reduced tariffs on imported equipment.

		Inn				
Location of Suppliers	High 1	2	3	4	Low 5	No Response
Canada	1	0	1	4	1	4
Elsewhere	3	3	0	1	0	4
Source: Survey	y, 1985.					

 Table 4.3: Perceptions of Forest-Product Firms about the Innovativeness of

 Equipment Suppliers Located in Canada and Elsewhere

In situations where R&D departments are needed to assess equipment purchases, foreign subsidiaries often channel this responsibility out of the country. This further reduces the potential for technological liaisons between equipment suppliers and forest-product companies.

Technological Liaisons: Forest-Product Firms and Cooperative Laboratories

Table 4.4 shows the relative importance of liaisons between in-house R&D laboratories and the main cooperative laboratories and other institutions, according to R&D managers of forest-product firms.

The relative importance given to links with Paprican is not surprising. Paprican is a large organization that is supported by all the respondent firms. Its R&D is oriented toward pulp and paper as is that of the in-house laboratories. But it is Paprican's basic research capability that the respondents value the most.

Liaisons with Feric and Forintek are mainly seen as "useful" rather than important or significant. The kinds of R&D these organizations perform are given low priority by in-house R&D laboratories. Their concern with technology transfer makes them less attractive as R&D suppliers. In Forintek's case, its privatization in 1981 resulted in confusion that has only recently been dispelled.

Cooperative R&D: Substitute for In-House R&D?

The lack of in-house R&D has been a problem in the Canadian forestproduct industries throughout the 20th century. To help compensate

Table 4.4: Relati Corporate R&D	ve Impor Laborato	tance of I ries and S	Liaisons Selected	between External	Organiz	ations	
Redative trance	pinals	t and Man	fetite fetic	Fointe	+ Paginci	r Univer	Stie ⁵
Significant	2	1	1	0	6	0	0
Important	1	4	1	0	1	2	1
Useful	3	3	3	6	4	4	1
Unimportant	5	3	4	4	0	4	8
No response	0	0	2	1	0	1	1
Source: Survey, 1	1985.				_		

for this deficiency the federal government was instrumental in setting up and supporting Paprican. The government also established its own forest-product laboratories, the EFPL and WFPL. During the 1960s and 1970s, however, there was a growing realization that government R&D does not effectively substitute for corporate in-house R&D.²⁷

In the mid-1970s, the federal government decided to reduce substantially its direct involvement in forest-product R&D. In particular in 1979 it decided to privatize its two main forest-product laboratories in Ottawa and Vancouver by withdrawing financial support. The assumption was that the industry would collectively pay the operating costs (given that the capital equipment was provided free) and create Forintek. This decision implied a commitment to cooperative R&D and a belief that cooperative R&D would in large part substitute for in-house R&D.

That belief is wrong. Although firms can survive without in-house R&D if they have staff capable of adapting technologies developed elsewhere, such firms are at a disadvantage. They are less able than firms with in-house R&D groups to exploit the expertise of research institutes such as Paprican. Moreover Paprican provides "only a small proportion of the new technology pool that is available" and firms lacking their own R&D effort will miss "major opportunities."²⁸ For example, MacMillan Bloedel's in-house R&D group generates technologies (in such diverse fields as corrosion, log transportation, pulping processes, printing papers, and building products) that are appropriate to its location, its resource supply, and its markets.

Managers of in-house forest-products R&D programs agree that their activities could not be replaced by cooperative laboratories. In fact, their views on this matter were recently summarized by Dr Forgacs, MacMillan Bloedel's vice-president of research and development, who said that Paprican is unable to provide the kind of firm-specific contributions generated by MacMillan Bloedel's in-house R&D group.²⁹ Rather MacMillan Bloedel, and other firms with in-house programs, perceive it as Paprican's role to perform long-term basic research and to augment the supply of highly trained scientists.

The view that in-house and cooperative (and government) R&D are complementary, rather than competitive, is supported by a growing literature.³⁰ Thus, as Cohen and Mowery note, arguments that favour more cooperative (and government) R&D overemphasize the "appropriability problem" of in-house R&D, that is the difficulties companies face in appropriating *all* the returns from their investments in R&D.³¹ The appropriability problem limits company investment in R&D and is used to justify government support for such activity.³² But the fact that a large proportion of industrial R&D in OECD

countries is conducted in-house testifies to a widespread belief that a significant proportion of the returns on in-house R&D *is* appropriable and is *not* transferable at negligible social cost.³³

On the other hand cooperative R&D has many drawbacks. The main one is that it cannot provide firm-specific or in some respects even nation-specific advantages, which means that cooperative R&D leads to adaptive and dependent technological strategies. It is costly and risky to transfer technology: a cooperative R&D lab will not succeed unless firms are equipped to absorb its research results. In the United Kingdom and the United States, association laboratories in many industries have only achieved mixed success. There are also limits to how much Canadian forest-product firms are willing to pay for cooperative R&D: Feric, Forintek, and in some ways, even Paprican, still rely on government support. In the absence of in-house R&D, especially in wood harvesting and wood processing, there are strong pressures, particularly on Feric and Forintek, to be more developmental and concerned with relatively short-term projects.

Attitudes toward Government R&D Policy

All survey respondents in forest-product firms and equipment suppliers with in-house R&D programs thought the government should support R&D. Nobody claimed that incentives were crucial to R&D, but they did regard them as useful. All respondents considered tax incentives, including tax credits, to be effective forms of R&D assistance. MacMillan Bloedel has also argued in favour of a cash advance option in years when firms have little or no taxable income.³⁴ Feelings were mixed regarding government grants: R&D managers within forest-product firms did not think they were effective; however, a majority of R&D managers within equipment suppliers thought otherwise.

The use of R&D grants available from government agencies has been minimal among forest-product firms with in-house R&D groups, partly because the application process takes too much time, and partly because of concerns about secrecy. Government grants for R&D are, however, more important to equipment suppliers, although some applicants have not been pleased with their experience. One larger firm had unsuccessfully attempted to obtain four grants from federal government agencies. It argued bitterly that R&D granting programs strongly favour smaller companies, a bias that it considered to be a waste of time. No doubt this attitude was influenced by the fact that two of its former employees had received government support when they recently left to form their own company as a direct competitor. On the other hand, three of the leading R&D performers among equipment suppliers were relying on government grants for up to 10 per cent, 30 per cent, and 50 per cent of their R&D funding. Among the federal R&D programs the Industrial Research Assistance Program administered by the National Research Council was the most frequently used.

Two forest-product firms argued that Forintek should not have been privatized because the real need is for more basic research. In their view the result of privatization is that more people are scrambling for the same dollar.

The R&D managers within equipment companies suggested several ways to enhance the usefulness of government R&D granting programs to their industry. First, they argued that the government should provide greater overall support to innovation, including subsidizing prototype development in Canada. In fact, the latter has occasionally happened, for example, when the government sponsored the adoption of integrated process control in an Ontario mill. Some respondents argued the need is for a more systematic and centralized approach along these lines.

Second, they argued that government grants should be used to encourage more standardization in the products of equipment suppliers. The so-called "mouse trap" problem, whereby each company wants to have its own slightly different technology, is widely recognized. There is a problem in trying to get forest-product companies to agree on technical specifications for particular kinds of machines. A recent example is the failure to establish specifications for an appropriate silviculture machine. Customers and suppliers tend to have their own ideas. Moreover, they argued that agencies such as Feric are actually making this situation worse by supporting new product development by individual manufacturers on an ad hoc basis. One way of standardizing specifications regarding new products would be for cooperative laboratories to ask for proposals, for example, with respect to a desired type of silvicultural machine. The government could subsidize the proposals and allow the good features of each to be incorporated in a winning design.

Commentary

In-house R&D by both forest-product firms and equipment suppliers in Canada continues to be weak. This weakness, especially among forest-product firms, is widely recognized within the industry. The usual explanations for this situation are that there is a lack of incentive to conduct R&D and that the market for new technology is too small. Both may be challenged. The weakness in in-house R&D is deep-seated. It is enhanced by a high level of foreign ownership.

To help compensate for missing in-house R&D both government and industry have supported the growth of cooperative laboratories. But cooperative laboratories cannot substitute for in-house R&D, because they cannot provide firm-specific advantages. However, they can provide R&D to small firms that cannot afford their own programs; support projects in which social rates of return significantly exceed private ones; undertake basic pre-competitive research to complement in-house programs; and supply highly skilled personnel to industry. It might be useful to stimulate a discussion of the roles and goals of cooperative R&D in the Canadian forest-product sector along these lines. That Canada should have strong cooperative forestproduct R&D is not in question. What is clear is that it can not substitute for Canadian in-house R&D by industry.

Canada also lacks the advantage of having strong domestic forestproduct equipment suppliers. Indeed, it is remarkable that there is not one large Canadian-owned equipment supplier. Once a domestic company reaches a certain size, it is usually taken over by a Scandinavian or American competitor. Canadian governments have not protected Canadian ownership. It is difficult to believe such passive acquiescence to takeovers by foreign firms would be so readily tolerated by the Japanese, Swedes, Finns, or Americans.

Another weakness that has been identified concerns the limited liaisons between the laboratories of the Canadian Forestry Service (CFS) and industry.³⁵ Such a situation is not surprising given that the provinces own the forests, the companies do the harvesting, and the federal government directs research. Although this study does not look at the functions of the CFS laboratories the lack of liaisons is disturbing and needs to be addressed.

In contrast to Canada, Scandinavia, notably Sweden and Finland, has developed strong innovative abilities on the basis of more explicit and coherent technology strategies. Scandinavia, like Canada, is a northern and peripheral forest-product exporting region and a major competitor. Scandinavia complements its considerable cooperative R&D with strong in-house R&D both by forest-product firms and equipment manufacturers. A key element of the Scandinavian approach to technology generation, in contrast to the arm's length transactions favoured by Canadian firms, is the close links that exist between individual forest-product firms and equipment suppliers who may operate under the same corporate umbrella.³⁶ For example, one of Sweden's forest-products giants, SCA, owns Sunds Defribrator, a world leader in the manufacture of pulping technology. Such close links foster sustained collaboration in mutually beneficial R&D. And although Canada has traditionally favoured "specific" solutions for "distinct" local circumstances, the so-called "mousetrap syndrome" or customized innovation, the Scandinavians have sought more general solutions. Although there is no doubt the Scandinavians have encountered considerable difficulties in applying their technology in other parts of the world, at the same time their large international firms with their global perspective on marketing and production have made it easier for them to modify "standard" products for other markets than it is for Canadian firms to modify and export their custom technology. As technology becomes more sophisticated, local conditions may not be as effective in providing "natural" protection against imported technology, even with respect to logging and wood processing.

Chapter 5

Modernization and the Choice of Machinery and Equipment

Forest-product corporations always have technology strategies, although they may be largely implicit. Every decision to purchase a large item of equipment, to modernize a mill, whether in whole or in part, or to build a new mill invariably involves the evaluation of emerging technology and the selection of equipment new to the firm.¹ Technology strategies reflect long-term corporate investment strategies.

During the 1950s and 1960s the forest industry invested in the construction of new mills to exploit new sources of timber. Most of these new mills were built in western Canada, especially British Columbia, and by the end of the 1960s the western industry was much more up-to-date and efficient than the eastern industry. Since 1973, however, there have been few new mills, especially in the pulp and paper industry, and the industry has invested in modernizing and streamlining its operations. The only new pulp and paper mills built at new sites in Canada since then have been at Port Cartier in 1975 (mothballed in 1979), Amos in 1981, and Quesnel in 1983. Capital expenditures, however, have been massive throughout this period notwithstanding the sharp decline that occurred in 1981. Over the past 10–15 years the Canadian forest-product industry has concentrated on "modernization" at existing sites.

Investments in plant and equipment reveal a demand for technology. The first part of this chapter reviews investment trends on the basis of the crude aggregate data available for 1971-83 and comments on the basic purpose of the investment decisions. Next it examines several case studies in the wood-processing and pulp and paper industries to determine whether firms are buying off-the-shelf technology or modifying existing technology and whether they are purchasing technology new to the Canadian industry or new globally. It identifies the factors that influence a firm's choice of equipment. It is essential that technology policy for the forest industry be considered as part of a broad investment strategy.

Capital Investments in the Canadian Forest-Product Industries

Historically, capital investment in the Canadian forest sector has been substantial and has accounted for an important share of expenditures for plant and equipment in the economy as a whole. In 1971, 1976, and 1981, for example, capital expenditures in the forest sector amounted to \$1145 million, \$1939 million, and \$4442 million or 4.5 per cent, 3.7 per cent, and 4.4 per cent respectively of *total* capital expenditures in the Canadian economy in those years. Even in 1984, a year when capital expenditures in the forest sector declined, they still accounted for 3.4 per cent of the total (Table 5.1). In most years the forest sector accounts for about one-quarter of capital expenditures in the manufacturing sector. If construction expenditures are excluded the relative importance of the forest sector increases by about 4 per cent with respect to capital and repair expenditures on machinery and equipment and about 3 per cent with respect to capital expenditures only (Table 5.2).

Within the forest sector the paper and allied industries account for the lion's share of capital expenditures (Table 5.3). In the peak year of 1981, for example, paper and allied industries accounted for 69.0 per cent of total expenditures and 77.6 per cent of capital expenditures on machinery and equipment. The wood-processing industries typically account for about 20 per cent of Canadian expenditures whether total capital expenditures or only capital expenditures on machinery and equipment are compared. Forestry, however, is relatively more important when total expenditures are compared than when machinery and equipment only are compared.

In fact, technology in the form of plant and equipment has become increasingly important during the 1970s especially in the pulp and paper industry. In 1973, for example, about \$8.86 billion worth of capital was employed in the pulp and paper industry; in 1983 this figure had increased to \$36 billion.² Associated with this trend is a sharp increase in the level of capital intensiveness as measured by capital employed per employee. As Woodbridge notes, "in 1950, for each employee, the industry invested \$22 000 of capital. Even as recently as 1970, this was still around \$81 000 per employee, in current dollars. By 1983, capital employed was an estimated \$385 000 per employee."³ Similar trends can be seen in the forestry and in the wood-processing industries. This rapid rise in capital intensiveness reflects the incorporation of expensive pollution controls, large-scale production units, rising capital costs, and the rapid development of new and expensive technology.

During the 1970s, capital investments grew more in central Canada than in British Columbia. In 1971, British Columbia, Ontario,

	Capi	Capital Expenditures (\$M)			est Sector rcentage of
	Canadian Totals	Manufacturing Sector	Forest Sector	Canadian Total	Manufacturing Sector
1971	25 621	4 378	1 145	4.5	26.2
1976	53 088	7 890	1 939	3.7	24.2
1981	100 456	17 383	4 4 4 2	4.4	25.6
1984	100 801	14 689	3 4 2 4	3.4	23.3

 Table 5.1: Capital Expenditures in the Canadian Economy, Manufacturing

 Sector, and the Forest Sector, 1971–84

Source: Statistics Canada, *Private and Public Investment in Canada* (Ottawa: Minister of Supply and Services, 1971, 1976, 1981, and 1984), cat. no. 61-206. Note: The forest sector includes the forestry, wood processing, and paper and allied industries.

Table 5.2: Capital Expenditures for Machinery and Equipment, notIncluding Construction Costs, in the Canadian Economy and the ForestSector, 1971-84

	Total Canadian Expenditures (\$M)		Forest Sector as Canadia	Percentage of n Total:
	Capital and Repair	Capital Only	Capital and Repair	Capital Only
1971	9974	6 6 7 4	8.7	7.7
1976	21 317	15011	7.2	5.5
1981	43 501	30712	8.4	7.5
1984	44688	29 594	6.5	4.7

Source: Statistics Canada, *Private and Public Investment in Canada* (Ottawa: Minister of Supply and Services, 1971, 1976, 1981, and 1984), cat. no. 61-206.

Table 5.3: Capital Expenditures within the Forestry Sector, 1971-84				
	1971	1976	1981	1984
Total expenditures (\$M)	1145	1940	4442	3424
Forestry (%)	14.8	18.6	14.3	15.6
Wood-processing (%)	20.2	20.0	16.7	20.5
Paper/allied (%)	65.0	61.3	69.0	63.9
Capital expenditures on machinery and				
equipment ^a (\$M)	515	823	2313	1384
Forestry (%)	8.0	11.1	7.4	7.2
Wood-processing (%)	21.9	20.3	15.1	20.5
Paper/allied (%)	70.1	68.6	77.6	72.3

Source: Statistics Canada, *Private and Public Investment in Canada* (Ottawa: Minister of Supply and Services, 1971, 1976, 1981, and 1984), cat. no. 61-206. ^a This category excludes all construction and repair expenditures on machinery and equipment. and Quebec accounted for 33.9 per cent, 16.6 per cent, and 12.2 per cent respectively of expenditures. In 1981, the relevant proportions were 38.6 per cent, 24.7 per cent, and 21.7 per cent. With the exception of the boom spending year of 1981, British Columbia's share of paper and allied expenditures has declined significantly (Table 5.4). The earlier technology gap between east and west has been reduced. From 1981-86 investments have been overwhelmingly concentrated in central and eastern Canada and technological obsolescence is now a major issue in British Columbia.

The effects of the recession of the early 1980s were more strongly felt in British Columbia than elsewhere, although the entire industry experienced serious problems in 1981–82. Large capital investments in 1979–81 had generated new capacity just as the worst recession since the 1930s began. These investments significantly increased the debt levels of the forest-product firms. The average debt-equity ratios for western forest-product firms escalated from 0.44 in 1979 to 1.07 in 1983;

Percentage of T	otal Expen	diture	
British C	olumbia		
Forestry	Wood	Paper/Allied	
	64.7	32.0	
59.7	48.6	21.7	
50.0	59.8	31.1	
56.9	58.0	20.2	
Percentage of T	otal Expen	diture	
Ont	ario		
Forestry	Wood	Paper/Allied	
	10.7	18.2	
14.6	14.6	33.1	
19.5	14.7	28.2	
23.6	13.7	29.0	
Percentage of T	otal Expen	diture	
Qu	ebec		
Forestry	Wood	Paper/Allied	
	10.6	15.4	
15.4	17.3	28.8	
17.7	12.4	24.3	
	Percentage of T British C Forestry 59.7 50.0 56.9 Percentage of T Ont Forestry 14.6 19.5 23.6 Percentage of T Qu Forestry 15.4 17.7	Forestry Wood 59.7 48.6 50.0 59.8 56.9 58.0 Percentage of Total Expen Ontario Forestry Wood 10.7 14.6 19.5 14.7 23.6 13.7 Percentage of Total Expen Quebec 10.7 14.6 19.5 14.7 23.6 13.7 Percentage of Total Expen Quebec 10.6 15.4 17.7 12.4	Percentage of Total Expenditure British Columbia Forestry Wood Paper/Allied 59.7 48.6 21.7 50.0 59.8 31.1 56.9 58.0 20.2 Percentage of Total Expenditure Ontario Image: Construct State S

Table 5.4:	Regional Distribution of Capital Expenditures
in the For	estry Sector, 1971-84

Source: Statistics Canada, *Private and Public Investment in Canada* (Ottawa: Minister of Supply and Services, 1971, 1976, 1981, and 1984), cat. no. 61-206.

the corresponding increase for eastern producers was from 0.61 to 0.76.⁴ With declining demand and profits and increased interest payments, corporate income dropped drastically. The 11 largest publicly owned producers, for example, enjoyed net incomes of \$720.3 million in 1980 and \$411.2 million in 1981 but lost \$125.1 million in 1982.⁵

Clearly, the western-based companies have been hardest hit and have experienced higher debt-equity ratios, lower profits, and lower net income. In 1984 and 1985 western firms continued to suffer the most. Greater reliance on solid wood products (as opposed to pulp) and on open market transactions, and emphasis on less processed commodities and higher debt-equity ratios are important factors accounting for the severity of their problems. Eastern firms, in part because of their greater share of older plants, had received substantially more government assistance during the 1970s and virtually all of the \$613 million spent in the pulp and paper modernization program that began in 1979.⁶

Although the western industry remains stagnant, with a low level of investment, the eastern industry has been more aggressive in pursuing investment, at least in part because of the availability of substantial government subsidies. In principle, however, not many forest-product firms profess support for these subsidies. The main concerns are that they have been awarded for political rather than economic reasons and they have been larger than necessary.⁷ Moreover, there are questions about whether the subsidies, which were awarded to a large number of firms, enhanced the efficiency of the pulp and paper industry.

The Role of Imported Machinery and Equipment

Technology imported in the form of equipment has always been important to the Canadian forest-product industries. During the 1970s and 1980s the value of such imports excluding construction equipment has typically been substantially higher than the value of exports (Table 5.5). The forest-product industries have long lobbied for dutyfree imports of machinery on the basis that access to the lowest priced and latest technology is essential to their competitiveness. Certainly, imports increased their share of the domestic market from 30 per cent in 1965 to over 50 per cent during the 1970s and 1980s (Table 5.5). Admittedly, the export-domestic production ratios of the Canadian forest-product equipment industry has similarly increased (Table 5.5). Nevertheless, Canada has a substantial balance of payments deficit in forest-product equipment trade.

renormance					
	1965	1970	1975	1980	1983a
Domestic Market (\$M)	158	247	421	650	612
Domestic Production (\$M)	130	205	340	617	485
Exports (\$M)	20	72	151	360	186
Exports as a %					
of Domestic Production	16	35	45	58	38
Imports	48	115	232	393	312
Imports as a %					
of Domestic Market	30	46	55	60	51

Table 5.5: Canadian Forest-Product Equipment Industry Trade Performance

Source: Data obtained from Statistics Canada by the former Department of Regional Industrial Expansion, Machinery and Electrical Equipment Branch. ^a Data for 1983 are estimates.

Table 5.6 provides a more detailed indication of Canada's international competitiveness in forest-product equipment. Canada exports products in all major categories. Relative to international competition, Canada's greatest strength is in woodland equipment. In contrast, the import values of pulp and paper machinery, woodworking machinery, and sawmill equipment are greater than export values. In addition, Canada imports more technology in the form of licences and services than it exports. In general, Canada's exports go to the United States and, although the United States is the source of most forest-product equipment imported into Canada, the Scandinavians have been making strenuous attempts to penetrate the Canadian market. In 1981, a peak spending year, the Swedes and Finns were particularly successful, especially with respect to chain saws and pulp and paper equipment. In recent years, Scandinavian companies have been actively acquiring Canadian firms as a way of penetrating the Canadian market

Modernization in the Pulp and Paper Industry: Case Studies

In recent years the desire to introduce high-yield pulping methods and/or to introduce new paper-making technology has dominated investment decisions by the pulp and paper industry. Only two new mills, at Quesnel and Amos, have been built; most projects have focused on modernizing existing facilities. Many modernization projects have been expensive. The leading twin-forming technology, for instance, is costly and a new paper machine of this type can rarely be installed for less than \$50 million and costs considerably more if new pulping facilities are involved.

1971		19	1981		1984	
\$000	(% U.S.)	\$000	(% U.S.)	\$000	(% U.S.)	
8 1 2 6	(57.2)	24 169	(6.1)	23115	(7.7)	
29474	(64.0)	75 006	(74.9)	177 332	(95.6)	
17 185	(44.3)	77 389	(36.2)	65 552	(50.3)	
4 354	(78.2)	24 820	(57.0)	29715	()	
1719	(74.2)	16 937	(78.8)	51 328	(82.8)	
13618	(57.2)	98 680	(54.0)	81 923	(76.2)	
74 476		317 001		428 965		
1971		1981		1984		
\$000	(% U.S.)	\$000	(% U.S.)	\$000	(% U.S.)	
649	(49.9)	6 382	(35.8)	5 8 9 7	(52.5)	
21618	(98.3)	65 641	(94.9)	137 227	(94.6)	
4 206	(25.0)	53107	(62.9)	50182	(33.2)	
6 0 9 0	(70.9)	36 902	(81.2)	46 524	(66.4)	
13 169	(73.4)	87 645	(57.2)	102811	(62.7)	
32814	(29.3)	152 099	(31.8)	88 172	(66.9)	
78 546		401 776		430 813		
	\$000 8 126 29 474 17 185 4 354 1 719 13 618 74 476 19 \$000 649 21 618 4 206 6 090 13 169 32 814 78 546	\$000 (% U.S.) 8 126 (57.2) 29 474 (64.0) 17 185 (44.3) 4 354 (78.2) 1719 (74.2) 13 618 (57.2) 74 476	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	

Table 5.6: Exports (Including Re-Exports) and Imports of Forest-Product Equipment and Papermaker's Felts, 1971, 1981, and 1984

Statistics Canada, Imports by Commodities (Ottawa: Minister of Supply and Services, 1971, 1981, and 1984), cat. no. 65-007.

Scandinavian manufacturers are in the forefront of this modernization. Firms such as KMW, Valmet, Sunds, Raute, and Jaalvaara, as well as the longer established Kamyr, have recently penetrated the Canadian market to compete against Canadian-based suppliers, such as the American-owned Beloit and Black Clawson Kennedy and Dominion (now taken over by Valmet). The German manufacturer, Voith, has also won its first Canadian sale for some time. It is seeking to increase its penetration from its recently established facility in Brazil; however, the really fierce competition in this area is from the Scandinavians.

Approaches to Modernization

Case A involves the partial modernization of a pulp and paper mill in Quebec. The firm had decided in the late 1960s/early 1970s to modernize its pulp and paper facilities.⁸ The modernization of the mill under study began in 1976-77 with replacement of one machine; this was followed in 1982 by a decision to invest over \$40 million to replace another machine. The firm's plan is to modernize the remaining machines sequentially. The underlying stimulus to its modernization strategy has been to improve paper quality and reduce costs at a time when the market has been moving to offset printing, which requires a better quality sheet.

Case B involves the partial modernization of a newsprint mill in eastern Canada. The plan was conceived by a foreign-based parent company that would not go ahead with modernization unless a partner could be found to share the costs. It took 18 months for the firm to find a suitable partner, also foreign. For \$50 million the latter obtained a 33 per cent share of the mill. As in case A, the firm decided to rebuild two old machines at the same site rather than build a new mill next door. The \$150 million modernization involved replacing an old low-yield sulphite mill with a high-yield sulphonated chemimechanical (SCMP) pulp mill. The idea for the modernization was accepted in 1977, construction started in 1980, and the mill was completed in 1982.

Case C involves setting up a new tissue paper machine in a new building adjacent to an existing plant. The modernization plan began to crystallize in the late 1970s. The \$60 million investment was given the go-ahead in October 1981, site preparation started in February 1982, building construction started in May 1982, and by May 1984 the mill was operational. The original plant, consisting of two machines, remains intact and the new machine has doubled capacity and increased product quality.

All three projects focused on "in-site" change and quality

improvement. The decisions regarding timing, financing, and whether to rebuild, replace, or add a paper machine were made at the corporate level; head offices also set parameters for subsequent decisions. To administer the projects on site the firms established networks of committees headed by "project teams," who in addition to liaising with head-office, were responsible for selecting machinery and equipment and seeing the project through. All three firms chose a middle manager with engineering background and plant experience, to lead the team. Other members were also typically seconded from plant administrative positions, such as the mechanical engineering manager. A firm would temporarily expand the project committee for a specific task: for example, including a labour representative when new equipment was being evaluated. In addition, all three, as is customary in North America, hired engineering consultants to help with, for example, employee training, mill design, and equipment selection.

The three firms recognized the importance of training their work forces to operate new and increasingly sophisticated technology. The firm in case B, for example, spent over \$1 million on a training program; this included a two-volume training manual and an extensive lecture series (which included participation by consultants) and was designed to teach the principles of paper-making as well as the workers' new tasks. Inadequate training can hinder the start-up and operation of new technology. Firms establishing new mills, rather than modernizing old ones, enjoy more flexibility in the choice of a work force.⁹

Firms A and B are most representative of industry thinking in their emphasis on the partial or total replacement of individual machines rather than of entire mills or, as in case C, on the addition of new plant. The underlying reason for this emphasis is a desire to minimize investment costs. In effect, it is argued that since new capital has a supply price and old capital does not, new capital that takes advantage of old capital will generate higher rates of return. Although this approach has merit, it also has adverse implications. Thus, existing mills are never entirely modern and product quality is likely to vary from machine to machine. Equipment of different vintages may generate production problems where processes are continuous. Machine replacement can result in considerable mill down-time because of unanticipated engineering problems. Machine replacement limits the choice of technology and tends to create a crowded mill environment that is unsatisfactory to the operators. Indeed, firms A and B noted that productivity gains had been disappointing primarily as a result of the "incremental" in-plant approach to modernization. In contrast, case C's modernization plan

was implemented smoothly and management is completely happy with machine performance and plant layout. Cases A and B (but not C) were supported by government subsidies.

Factors Affecting Equipment Choice

In each case study, the most expensive element of the modernization program was new "twin-forming" paper machines. What factors affected that selection? Each project team was charged with identifying the best, proven technology appropriate to mill circumstances. Case A's project team visited 10 mills around the world including one in Japan. A representative of firm B visited mills in Scandinavia, Germany, and the United States as well as Canada. With respect to case C the project team visited six mills in Europe and the United States. The extent of each search depended on the type of paper machine required by the firm and its distribution among existing mills. Firm C's (a tissue paper manufacturer) search processes, for example, were more limited than those of firms A and \hat{B} (newsprint manufacturers) because there were fewer twin formers of the multi-purpose type desired in operation and not all mills were willing to allow the representative of firm C to enter their mills. Visits to mills were supplemented by discussions with equipment suppliers.

Eventually the project teams had to choose between several (three to five) twin formers on "technical" grounds: product quality, operating efficiency, machine configuration, accessibility for maintenance, technical risk, post-sales service, financing, price, and so on. Two of the firms adopted formal evaluation procedures based on a method developed by Kepner and Tregoe.¹⁰ This method requires team members to weigh each criterion in terms of relative importance and assign a score (out of 10) to each machine. The weight and scores were multiplied and the totals summed for each machine. The two firms using Kepner-Tregoe expanded their project teams during the evaluation. One team took on three outside consulting engineers, a union member, and a representative from the foreign parent, and each team member did a separate evaluation. The team sought a consensus and recommended a twin former to head office for further "commercial" (rate of return on investment) analysis.

The three firms ranked product quality as the most important variable. Price was considered the third most important variable by one firm and of lesser importance by the other two firms. However, twin-forming technology is still new. When suppliers manage to reduce the qualitative differences between machines price may become a more important consideration. (The decisions by Beloit and Voith to set up twin-forming machinery in Brazil may significantly affect price differentials, especially if favourable financing can be arranged.) Of the four paper machines purchased by the three firms, A, B, and C, two were researched and developed in the United States (although manufactured in Canada) and one was researched, developed, and manufactured in Sweden. The fourth machine was a Canadian-developed Papriformer, a line that has been discontinued following Valmet's takeover of Dominion Engineering.

Canadian sourcing of equipment was not considered to be of major importance to the case study firms. The firm that purchased the Papriformer did favour its Canadian origins, but this factor was not critical. Much foreign-originated technology is manufactured in Canada so that questions on sourcing should recognize that technology is imported via licensing as well as equipment. Although the author did not have information on all the equipment purchased for the three projects, it is likely that (*a*) in at least two cases more than half the equipment purchased was developed outside Canada and (*b*) in one case more than half by value of the equipment purchased was imported.

Virtually every item of equipment purchased for the three projects had already been adopted elsewhere, with the notable exception of one project in which the new paper machine was fed by a new pulp mill that used a pulping process recently developed by the firm's in-house R&D group. Perhaps if in-house expertise is available firms are willing to be more innovative. Indeed, in this case the R&D group was closely involved in the transfer of the technology to the mill site and it recommended the equipment supplier, a Swedish firm. In general, however, "proven equipment" dominated technology choice, except in those few instances involving the transfer of in-house technology.

Modernization in the Wood-Processing Industry: Case Studies

These case studies are based on two mills that modernized their total wood-processing operations. One plant (D) is located in interior British Columbia; the other (E) is on the coast.

Approaches to Modernization

Case D involves the conversion of a plywood mill to a modern sawmill. A study of the wood supply and the market conducted in 1980 provided the long-term rationale for this modernization: the immediate stimulus was the recession. Once head office had decided to modernize, a project coordinator was hired from another forestproduct firm. Construction started in 1981; it was put on hold, after the foundations were poured, until July 1983. The mill was completed in May 1984. The throughput is 7000 logs per shift and the mill operates on two shifts. The principal market is the United States.

Case E involves a decision to modernize an old west coast sawmill rather than shut it down. The modernization, which cost over \$15 million, was organized internally and headed by a project manager experienced at modernizing sawmills. A consulting company was hired to do the engineering, construction, and electronics. The goal of modernization was production flexibility from new equipment capable of cutting lumber to order from logs whose butts varied from 0.3 to 1.5 metres. The firm is planning to sell 30 per cent of the modernized mill's output in Pacific Rim markets, in an attempt to reduce the mill's historic reliance on dimension lumber for the American market.

Selection of Equipment

The broad investment goals for the projects were established at the corporate level. Project teams were established to develop and implement mill concepts in detail. The main inputs to this process for case D came from managers of other mills and from head office. Consultants were hired to do the design. Once the overall concept was set, the project coordinator visited other mills throughout British Columbia. It is standard practice in the sawmilling industry to use knowledge gained during visits to other mills. Between 1980 and 1983 the only change in the mill concept for case D was to reduce its size.

Both firms were conservative in their choice of equipment. Apart from a few programmable logic computers, the equipment they chose was conventional "proven" technology. They avoided prototypes and even machinery that they did not see in operation.

Equipment was first evaluated technically. Most of the technical evaluations were done internally and, except with respect to electronics, they were coordinated by the project manager. Without an R&D group or even a central engineering department in Canada both firms relied heavily on these project managers and one or two other individuals to keep abreast of technological change and make appropriate choices. One firm did contact Forintek to help resolve an internal debate concerning equipment. Technical evaluation was followed by commercial evaluation: suppliers submitted quotes, then the cost of spare parts and cost and speed of after-sales service were looked at. Decisions about equipment were not difficult since cost was an important factor. One firm, which would have preferred to buy locally, ended up purchasing electronic components from the United States. The number of suppliers submitting quotes on each piece of equipment ranged from 1 to 10.

Both firms adopted a non-innovative approach to modernization that emphasized labour productivity gains as the primary goal. In case E, for example, the number of jobs dropped from 240 to 170, as two old planer mills were replaced by one more efficient one. In case D, employment totals dropped from 350 to 180, but the working environment and skill levels improved. In particular, the new mill, in contrast to the old, is heated, dust free, well lit, and less noisy. Much of the physical labour has been eliminated. Neither project manager thought deskilling had occurred. They noted that for the maintenance people, jobs are more challenging and their skills had to be upgraded. In addition, production line employees have to make decisions — for example, how logs are examined and cut — that affect productivity and returns, and manual dexterity with computer controls is a new job requirement.

Modernization in the Woods

Modernization by mechanization has been an ongoing theme in woodharvesting operations. Opportunities for mechanization remain substantial and the cost of modernization in the woods is generally not as great as in the mills. However, the variety of trees and of their environments makes mechanization difficult. Power saws remain the preferred method of timber cutting in most parts of the country and mechanization of silvicultural operations is still in embryonic stages. These variations have encouraged a diversity of equipment in the woods and an entrepreneurial/engineering emphasis on adapting technology to meet local conditions. Many would argue, however, that the diversity of equipment found in the woods is greater than necessary.

With respect to demands for technology in the woods, according to Silversides, it has not been

...possible to obtain a consensus in industry on what route to follow. Studies of the three logging systems, shortwood, tree length, and full tree, based upon direct costs, shared little real difference in cost so there was no incentive or financial justification to switch from one system to another. This reinforced the fragmentation of the machine market. Along with a lack of commitment by the forest industry there was a lack of understanding of systems. As a result, companies faced with an array of new machines were like children in a candy store. They bought one of these and two of those machines, often incompatible so their inherent capabilities were never fulfilled. This tended to put mechanization into disrepute.¹¹

The situation has been complicated in recent years by the cost of capital rising faster than that of labour. Also, a lack of success in developing tree harvesting machines has led Canadian equipment manufacturers to slacken their effort. Certainly, Canada's failure to build upon the new machinery of the 1960s, notably the skidder and early types of tree harvesters, has allowed the Scandinavians to take the technological lead. Silversides has argued that regional preferences and lack of knowledge about alternatives have militated against a concerted effort in Canada to develop appropriate silvicultural equipment.¹²

Case Study of Equipment Selection

Information for this case study was obtained in an interview with a general manager of woodlands and sawmills of a firm based in eastern Canada. He summarized the characteristics of equipment chosen to mechanize the firm's cutting operations. The firm is extremely conservative in adopting new equipment. It rents machines from suppliers and only occasionally buys them outright. It rents feller-bunchers, for example, which cut about 25 per cent of its wood. In addition, the firm no longer buys prototypes. It considers it was spending enough on R&D without using its woodlands as a guinea pig. Nevertheless it permits experimentation on its woodlands by "competitive renting" of models from different manufacturers and by allowing suppliers to try out their equipment.

The firm's decision to buy a machine is based on costs. In this respect there is occasional conflict with head office. Woodland managers, for example, want to keep on buying feller-bunchers and justify the decision in terms of expected labour shortages and improved safety. However, especially where trees are relatively small, the power saw remains the most economical method of cutting trees. Whereas head office is clearly in tight control over financial matters, local input is very important in determining the type of machine and choice of supplier. Local woodland managers are in constant contact with suppliers and dealers and are knowledgeable about local operating conditions. For these managers quality and servicing are important. There is no doubt that the head office's emphasis on costs tends to reduce their options with respect to choice of machines. Although head office has no obvious preference among makers, some local managers do.

Discussions between buyer and suppliers about sales of new machines contribute to technological innovation. For example, the

case study firm recently purchased 66 wide tires to put on skidders. It experimented with tires from four firms, which led to drastic modifications.

Conclusion

During the past decade the Canadian forest-product industries have increased capacity and introduced new technology. In sawmills and pulp and paper mills there have been significant changes in mill environments and operating procedures. During this same period concern for the technological capability and innovativeness of forestproduct firms and their suppliers has increased. It is widely supposed in the industry that Scandinavian, German, American, and Japanese firms are on the leading-edge in terms of creating and adopting new technologies. Despite the massive investments of the past decade the rate of diffusion of technology in the Canadian industry is now widely considered to be inadequate. In particular, any prior claim the western Canadian industry had to be at the state-of-the-art technologically has now disappeared. Indeed, the view that the Canadian industry is technologically lagging behind its main competitors is widespread among senior industry personnel with worldwide contacts.

The apparent paradox between massive investment in "modernization" and a widening technological gap with major rivals can be explained in several ways. First, investment decisions in Canada almost invariably emphasize "proven equipment." Adoption of innovative machinery is rare. Before choosing equipment Canadian buyers want to see it in operation. Second, although changes in technology have occurred in reaction to market demands, the industry has not foreseen these demands. Canadian industry has continued to rely on natural advantages, as it always could in the past. Third. decisions about investments in the Canadian forest-product industries have been dominated by short-run financial considerations. This tendency has resulted in step-by-step upgrading or replacement of individual machines at periodic intervals rather than in the rebuilding of entire mills. Moreover, equipment and buildings are only replaced when operating revenues fail to cover operating costs.¹³ This piecemeal approach to modernization neglects the dynamics that exist between technological and market changes.

In the Canadian forest-product industries, each firm makes its own plans. Resulting competitive investment strategies put pressure on financial resources and market opportunities and can lead to overcapacity for individual firms. Federal government policies have supported this state of affairs. The Canadian pulp and paper industry, especially in the east, has received considerable federal government financial support, notably from the former Department of Regional Industrial Expansion (DRIE) and its predecessor, the Department of Regional Economic Expansion (DREE). Funds from these departments were available to all firms to maintain old mills in old locations and, less recently, to generate new capacity in new locations. Primarily concerned with employment, federal subsidies were not guided by a comprehensive strategy for forest industries and have supported a fragmented approach to investment decision-making within the industry.¹⁴

The Scandinavian approach to modernization differs from the Canadian approach in several respects. In particular, in Scandinavia domestically manufactured and designed technology is given high priority so that, for example, a typical mill modernization program would buy well over 90 per cent of its equipment from local sources. The close ties between forest-product firms and equipment suppliers also encourage innovation in, for example, new pulping processes and higher value papers. Moreover, the Scandinavians are more willing than Canadians to look at long-term consequences and marketing considerations. Compared to the case in Canada, debt-equity ratios are often higher and more firms favour entire mill replacement. Government support of modernization programs is also less constrained by short-run direct employment effects and tends to selectively favour stronger proposals.

In Canada, in contrast, despite a cumulatively high level of investment our mills are not equipped with the latest technology. Only a few of the larger firms seem to incorporate R&D into their thinking regarding investment strategies. Canadian firms lack explicit and aggressive technological policies. Technological efforts have been partial and increasingly threatened by short-run financial considerations. In addition, although both federal and provincial governments have "intervened" considerably they have no clear design for the industry with respect to the generation and diffusion of technology. There are no Canadian government goals to raise the forest industry's technological capability, to be a technological leader, or even to be a net exporter of forest-product technology. Is a philosophy of laisser-faire in this regard in Canada's interests? It is high time to formulate an innovation policy for the Canadian forestproduct industries.

Chapter 6

Promoting In-House R&D in the Canadian Forest-Product Industries

Free trade is almost a sideshow. The central issues of international trade policy now concern the relative speed at which national economies are evolving to higher value production.¹

The argument that we should let "the market" ease us out of declining industries is unconvincing, because the very same non-market pressures are operating right across the industrial spectrum.²

If the Canadian forest-product industries are to maintain, let alone enhance, their competitive position in global trade a commitment to technological innovation and excellence is essential. They need innovations that will help them use forests more effectively, that meet the exigencies of local conditions, that improve labour productivity and, most important, that permit rapid penetration of a wider range of geographical and industrial markets, especially higher value markets.

The Canadian forest-product industries estimate that during the next five years at least \$20 billion in new investment will be necessary simply to remain competitive and that more capital would be required to establish Canadian companies in a position of leadership.³ Inadequate profits have often prevented such investment; yet a more diversified industrial structure in which value maximization is given greater priority would enhance rates of return on investment and increase profits. Moreover, the enormous cost of modernization is a good reason for industry and government to develop a coherent innovation policy for the forest-product industries. Demands for new plant and equipment offer a massive opportunity to strengthen the supply industries.

The Constraints of an Export Staples Mentality

It will not be easy to convince Canadian forest-product firms (and supplying firms) to innovate more. Since their beginnings, when firms exploited Canadian forests on behalf of the British Admiralty, the Canadian forest-product industries have been dominated by an

"export staples mentality." The belief that the forest-product industries of Canada are doomed to remain marginal and therefore vulnerable units on the global scene has encouraged strong support for free trade to ensure continued free entry of bulk commodities into the United States.⁴ It has also undermined possibilities for more comprehensive long-term thinking and stimulated a strong conservatism toward in-house research, development, and innovation.

The forces suppressing innovation by a large proportion of the Canadian forest-product industries are deep rooted. Widespread reliance on adapting technology that has been tested elsewhere is in part a way of limiting the uncertainties that exporters already face. Moreover, historically foreign investment in the Canadian forest-product industries has tended to reinforce both the export of bulk commodities and technological dependence. Concentration on standardized products and mature technologies is not conducive to R&D and innovation; but without indigenous R&D diversification is severely restricted.

Access to international markets is critical to the health of the Canadian forest-product industries. The lumber industry is right to be concerned about protectionist sentiments in the United States. An increase in the American tariff on the import of lumber (or, as has happened, the imposition of a Canadian export tax) would definitely hurt the industry. At the same time Canadian policy must seek to go beyond enshrining the role of Canada as a marginal and passive supplier of cheap lumber to the United States. The long-term challenge facing the lumber and other forest-product industries is the extent to which, and the speed with which, they can switch to more highly processed products. The same challenge faces all so-called mature or smokestack industries in advanced countries.⁵ It is in this sense, even for the forest industry, that free trade is a "side show."

If the Canadian forest-product industries are to become less marginal they will have to make a greater commitment to innovation. That will require a fundamental change in the attitudes of decision makers. They must be convinced that aggressive corporate and government science and technology policies can stimulate and support major innovation.

The 1980s: A Window of Opportunity?

Are these basic changes in attitude likely to occur in an industry where prevailing attitudes toward research, development, and innovation can be traced back over 200 years and have been enshrined in trading, tariff, and corporate structures? One hopeful sign is the fact that the turbulent 1970s were followed by the deepest recession in 50 years and a significant restructuring of the industry. There are no quick ways to promote more innovative attitudes: R&D tax incentives are already generous and the Canadian forest-product industries have long competed on a more or less free trade basis.

For at least three reasons, Canada now has another chance to enhance its comparative advantages in the forest industry. First, there is no longer any complacency about future growth: the severity of the recent recession has led firms to reconsider long-term strategies. In contrast to the early 1970s, job loss is feared, the wood supply is uncertain, and growth is not assumed. Second, firms are reducing their dependence on bulk commodities in favour of market diversification. This trend has been encouraged by the cost-price squeeze facing lumber and pulp producers, the severity of the recent recession, growing demands for high-quality products, and the achievements of the Scandinavian countries, which, although as remote as Canada from major markets and with smaller domestic populations, have rapidly moved up-market due to imaginative innovations. Canadian industry must move more aggressively in this direction.

The third and key reason is the trend toward Canadianization. Between 1979 and 1984, the level of foreign ownership dropped by about 10 per cent in all the major forest-product activities.⁶ This trend did not stem from the actions of the Foreign Investment Review Agency or any other government policy but from the restructuring of foreign-based corporations. For the most part when foreign firms have sold their Canadian operations the purchasers have been Canadian conglomerates based in Toronto and Montreal who now have an important position in the forest-product industries.

Canadianization is a prerequisite of more aggressive attitudes toward domestic innovation and market diversification. It means that more marketing and investment decisions are made in Canada. Canadian R&D policy may therefore have greater influence on the industry. Studies of Canadian industry in general indicate that federal R&D grants have more impact on the R&D budgets of domesticallycontrolled firms than on those of foreign-controlled firms.⁷

There is of course no guarantee that Canadianization will automatically lead to higher levels of in-house R&D and greater domestic innovative efforts. Will the Canadian conglomerates be prepared to support greater risk-taking? At present they have a reputation as conservative institutions whose growth policies favour acquisition over internal investment and who emphasize short-run financial considerations in maintaining control over operations. Their subsidiaries are not encouraged to launch risky new projects. However, the sheer size of the conglomerates would certainly prove a great advantage should they decide to promote innovation. It makes it easier for them to justify investment in risky activities, to plan over the long term, to fend off corporate predators, and to increase Canadian control by acquisition of foreign subsidiaries.

Because conglomerates control activities in different industries they can potentially establish production and technological linkages between equipment suppliers, forest-product firms, and construction companies, and they can engineer marketing connections. Also they often have overseas subsidiaries that enable greater flexibility in industrial planning and marketing of innovations.

Conrad Black has recently justified the presence of huge Canadianowned and -controlled conglomerates as the only effective way of offsetting the power of large foreign-controlled multinationals in the Canadian economy.⁸ He urges that the role of conglomerates in preserving a degree of sovereignty in the Canadian economy should be formally recognized — not attacked by more rigorous federal competition laws. Black is essentially offering a kind of social bargain between the most powerful corporate interests in Canada and the government. This offer should be seriously considered if conglomerates would in return promise to enhance Canadian industrial strengths, especially by committing themselves to increased R&D.

The acceptance by Canadian conglomerates of an obligation to a broad social interest may be Canada's last chance to build industrial strength through innovation in the resource sector. Although R&Dbased small and medium-sized firms in high-value-added segments of the forest-product industries can also play a part, given the structure of the industries, whether attitudes toward innovation within the sector change significantly depends on leaders in the conglomerates and other big firms.

Getting R&D out of the Lab and into Production

The challenges of mature industries are becoming more and more like those of high technology: automation of production, incorporation of advanced technology into the final products, the necessity to compete in global markets, and the need for a more educated and professional labour force.⁹

To develop their full potential the Canadian forest-product industries will have to become more innovative. Policy makers must remember that innovation includes not only the science and engineering activities of the R&D system but also the entrepreneurial (marketing, investment, industrial relations) activities of the production system.¹⁰ An increased commitment to R&D is not all that is required.

The aim of the following recommendations is to encourage the commercial application of the results of R&D so as to maximize the competitiveness of the Canadian forest-product industries. These recommendations, which are directed toward industry, the cooperative research laboratories, and government, are concerned with, first, the long-range production strategies of forest-product corporations; second, the nature of technological planning ("technology strategies"); and, third, the nature of the forestry sector R&D system. Finally, suggestions are offered on how business and government leaders might help stimulate greater concern for innovation in the Canadian forest-product industries.

Toward Flexibility and Value Maximization in Forest-Product Manufacturing

In the past the adoption of "proven" equipment and cost minimization has taken precedence over innovation in the Canadian forest-product industries. Technological planning has typically been an implicit process and emphasized adaptive R&D, despite a few examples of Canadian technological leadership, such as the development of twin-forming technology (see chapter 3). Characteristically, however, Canadian forest-product firms (and equipment suppliers) have made no attempt to initiate technical or product change. Only a handful of firms have developed noteworthy in-house R&D programs and sought to establish themselves in the technological vanguard of the industry.

The emphasis on adaptive R&D and conservative attitudes toward innovation have been consistent with Canada's historic role as a marginal supplier of bulk commodities. Canada will and should continue to be an important world producer of bulk commodities. However, fewer plants are needed for this, because the size and speed of machines have increased and demand has declined. On the other hand, markets for higher value and more differentiated forest products have grown. Moreover, if the Canadian forest-product industries wish to escape their overwhelming reliance on the United States market, Canadian firms will have to cater to the distinctive requirements in terms of type, quality, and size of products of alternative markets, especially in the Pacific Rim. Therefore, if the Canadian forest-product industries are to develop their full potential, they will increasingly have to emphasize principles of flexibility and value maximization in their production processes. They will also have to make the concept of flexibility explicit in their investment plans, and to consider a wider range of technological choices.

A firm's "flexibility" is judged by how easily it adapts its geographic scope and strategy, internal structure, product design, production techniques, and design of industrial systems to changes, or anticipated changes, in market demands. Flexibility may be a characteristic of a specific mill or of the firm as a whole. Investment in in-house R&D is an attempt to promote the flexibility of the whole firm. As corporate environments become more dynamic, firms need to develop broadly based flexibility with more diverse products and proportionately more liquidity.¹¹

How firms enhance their flexibility to meet changing market needs depends upon particular circumstances. During the 1950s and 1960s several west coast firms improved flexibility by concentrating lumber, plywood, and pulp and paper operations on one site thereby providing for easy diversion of raw materials from one end use to another, as well as allowing for considerable cost savings, for example, in the use of energy. Those integrated facilities located on tide-water also enjoyed access to diverse markets and sources of timber.¹² Other more specialized factories may be able to sell to new geographical markets and/or differentiate their product by introducing more versatile technology. Sawmills, for example, can potentially manufacture lumber, pulp chips, particleboard furnish, energy, specialty products (for example, sawdust for cattle feed) and thus generate multiple cash flows. If they are integrated with pulp and paper making processes as part of forest-product complexes, they can bring together a variety of engineering and technical skills and provide a focus for a variety of innovations.¹³ Another way firms can achieve flexibility is by investing in specialty mills.14

For the firm, "horizontal and vertical" diversification into new products for existing markets and new products made with old equipment extends the range of forest-products that can be manufactured from a given resource base and increases flexibility by permitting counter-cyclical revenue generation. If the opportunity costs of "related," if non-conventional, forest-products, such as chemicals and energy, increase rapidly, firms will be tempted to invest in these activities. In this regard, the extent to which the firm can diversify its use of the forest resource is partly determined by its technological capability. Similarly, such a strategy would exercise a firm's technological resources and in turn would enhance the range of potentially relevant innovations available to the firm.

How firms become flexible also depends on their size.¹⁵ Small firms can develop fast response to markets, high internal efficiency, and service to specialized market niches. In contrast, Canadian-based

multinationals can achieve market connections and understanding; wide investment, financing, and trading options; extensive networks to gather technical information; and higher rates of innovation. Canadian-based forest-product multinationals have the additional flexibility offered by direct operating presence and experience in international markets. Because they operate in such a wide range of rapidly evolving and complex environments these firms are under particular pressure to develop formal technology strategies.

An important corollary to increasing flexibility is for Canadian forest-product firms to move up-market. Wood processors and pulp and paper makers could give greater emphasis to higher quality grades of product, add manufacturing steps, and develop new products. Indeed, key technological leaders and R&D advocates within the industry have recently argued for a much greater commitment to enhancing the value of forest products manufactured in Canada.¹⁶ Opportunities for product development clearly exist, for example, lignin-based chemicals, new kinds of pulps (including fluffy pulps), specialty papers, and a variety of wood products for both decorative and structural purposes. In fact, the demands for new structural uses of wood are potentially massive, especially for non-residential construction and for preserved wood foundations in residential construction. Certainly there are barriers to moving up-market. They include tariffs, transportation rates, and the high cost of product development. As some leading companies realize, however, growth and profitability increasingly depend upon penetration of higher value market segments.

If the Canadian forest-product industry is to embrace valueadded production and more flexible production, the prevailing practice of processing as many logs as possible must give way to the practice of value maximization.¹⁷ Second, firms will have to market their products more aggressively, emphasizing direct identification and anticipation of consumer demands. Third, firms will have to spend more on technology and its development, absorption, and use.

Technology Strategies

....we have entered an intensively competitive period, in which technology and marketing have joined productivity as key strategies.¹⁸

There is a close interrelationship between marketing, production, and technology policies. An emphasis on production flexibility and value maximization principles in turn requires more explicit and innovative technology policies. This author therefore recommends that forest-product corporations establish technology strategies: that is, formalized mechanisms for assessing and implementing technological change.

In general, technology strategies spell out how firms integrate their "total technical resources...into a coherent, directed force to commercialize a continuing flow of technology in order to remain competitive."¹⁹ Technology strategies cover how firms monitor and evaluate technological information and how it is communicated within the firm, how technological needs are identified, the relative roles of internal and external sources of technological capability, internal R&D, and how, when, and where firms decide to incorporate new technology within investment plans. They are also concerned with levels of quality control, the skill level of employees, and training and retraining programs. Technology strategies are competitive weapons designed to encourage a stream of product and process innovations that will allow Canadian forest-product firms to compete effectively with American, Japanese, and Scandinavian firms.

Clearly, a technology strategy can only be properly implemented with the full support of the chief executive officer,²⁰ who can do this most effectively through a vice-president of R&D or technology planning. Direction at the senior executive level is essential because technology plans are intertwined with production, marketing, and investment decision-making. Moreover, even within the context of well-established R&D groups, long-term, costly, and uncertain endeavours such as MacMillan Bloedel's Parallam project cannot survive without the unequivocal support of the CEO.

Firms of all sizes, whether or not they have an in-house R&D group, have at least implicit technology strategies. In small firms, with few executives, technology planning will require much personal attention by individual entrepreneurs. Such entrepreneurs, however, can draw upon various sources of technological expertise, notably cooperative R&D laboratories, such as Forintek's sawmill improvement program. And the benefits to small firms of a broadly based investment in technological innovation and human resource development can be critical to their ability to compete.

The preparation of an explicit technology strategy by a larger firm might require an evaluation of the ergonomics of individual operations, the development of mill-wide computer plans for each mill, and mechanisms by which technological information is collected, stored, and transmitted within the firm. Abitibi-Price has recently established a Technology Transfer Unit designed to facilitate the diffusion of technological information within the firm, which might be a useful model for other companies (see chapter 2). As the effective use of advanced technology depends upon the skills of employees, technology strategies should specify plans, along the lines of the \$1.7 million annual training program recently introduced by Boise Cascade at Kenora,²¹ for ongoing training of employees. It is equally important that mill managers and marketing professionals know more about science and engineering. To meet this objective firms need to raise the level of formal scientific and engineering requirements for positions in marketing, production, and R&D departments; to create corporate (and mill) engineering groups, and to allow for regular paid leaves for seminars and sabbaticals. Improved use of existing technology can realize substantial benefits in a short time. MacMillan Bloedel, for example, reported saving \$28 million in two years following the introduction of a "quality program" at its Powell River mills.²²

From a long-range perspective, firms should identify their technological goals and identify the processes by which these goals are to be attained. Although individual firms cannot hope to be entirely technologically self-sufficient, in-house R&D groups offer substantial advantages. Given the increasing pace and complexity of technological change, and a greater commitment to flexibility and value maximization, these advantages will become more significant. Firms also need to be sufficiently flexible to establish specialized R&D groups wherever appropriate, for example, a highly trained computer systems group could develop and implement automation plans and generate highly specialized software. Recent decisions to eliminate three such groups by large Canadian firms are to be regretted.

Enriching the R&D System

For some time, senior executives in Canada's forest-product industries have argued for a greater commitment to R&D as an increasingly important source of competitive advantage.²³ This view has been buttressed by numerous reports, research articles, and commentaries.²⁴ Senior executives acknowledge the need for more industry-sponsored R&D in relation to government R&D and recognize that the close ties between the operating and research personnel of pulp and paper companies, association laboratories, and equipment suppliers in Sweden, Finland and, to some extent, the United States is a "significant" factor in the successful commercialization of technology in those countries.²⁵ But with few exceptions, Canada has failed to create an appropriate environment for industry to respond effectively. Despite the abovementioned pleas for more industry-sponsored R&D, there remains a widely held opinion that the forest-product industries are "open" with respect to technology transfer so that new technologies can be readily imported and adopted or initiated. In this view a local R&D capability is only necessary to the extent that new technology has to be modified for Canadian conditions.

Unfortunately, such a view begs the question as to why so many foreign firms invest so much in forest-product R&D. It vastly oversimplifies the situation by ignoring the costs, timing, and uncertainties involved in technology transfer and the competitive advantages with respect to lower costs of production and market diversification and penetration that can be derived by aggressive technology strategies. To develop technology as a competitive weapon in the Canadian forest-product industries it will be necessary to place a higher value on indigenous R&D, particularly that done in-house by industry. Cooperative laboratories, even though their priorities are controlled by industry, cannot properly substitute for in-house R&D. In-house R&D is the lynchpin of the entire forest-product R&D system.

The value of indigenous R&D for the Canadian forest-product industries is several fold. First, a major thrust of R&D in all resource industries is to develop technology appropriate to local circumstances. In the Canadian forest-product industries variations in climate, topography, soil, and vegetation have historically demanded distinctive and often imaginative solutions. Canadian R&D groups can create innovations to meet local priorities. Foreign firms will not develop technology in the form and at the time best suited to Canada.

Second, even in instances where it may make sense to adapt foreign technology, a Canadian R&D capability can, by thoroughly understanding imported technology, contribute to more effective bargaining, implementation, and refinement. Indeed, evidence from industry proves that innovativeness is positively associated with R&D capability and even the ability to import technology depends upon indigenous R&D.²⁶

Third, Canadian-based R&D laboratories can speed up the diffusion process. In their absence, innovation will be delayed by problems of implementation.

Fourth, indigenous R&D is essential for developing new forestrelated businesses; higher-value products; and a wide range of products in terms of performance, function, and aesthetics. Except under unusual circumstances, foreign-based R&D will not be concerned with maximizing market values within Canada from Canadian forests. Therefore, indigenous R&D is critical to Canadian hopes for generating more diversified and higher-value products from its timber.

Fifth, indigenous R&D is a key to the export of forest-product technology from Canada. Even after decades of missed opportunities

Canada could still become a major global supplier of forest-product technology in the form of equipment, services, and consulting if the close connection between export marketing and R&D is recognized.²⁷ Because costs are high in Canada our exports of manufactured end products must increasingly depend upon technological distinctiveness.

Sixth, indigenous R&D is essential if the implications of developments in high technology areas such as microelectronics, robotics, laser technology, and biotechnology are to be readily and fully appreciated by the forest industries.

Finally, a commitment to indigenous R&D is the best way to maximize employment in the forest-product industries. Productivity change may result in job losses for production line and maintenance workers, especially in sawmills. On the other hand, increased technological capability would protect existing jobs and create more R&D jobs in forest-product firms, more R&D and production-line jobs in the equipment supply industry, more jobs in any value-added or new business lines created and in linked activities. Also a greater commitment to the principles of forest management (and the associated research) would potentially increase employment.²⁸

There is growing evidence that private and social rates of return on investment in forest-product R&D are substantial even when the costs of failures are included and levels of risk discounted.²⁹ One authoritative study concluded that the returns from R&D in long established ("low technology") industries have been underestimated.³⁰

The Role of In-House R&D by Forest-Product Firms

In order to enrich the Canadian forest-product R&D system, therefore, this author recommends that senior executives in forestproduct firms establish or significantly increase in-house R&D.

In-house R&D provides individual firms with substantial advantages and fills at least two major roles that are difficult for other forms of R&D to emulate. First, in-house R&D allows firms to address problems that are peculiar to them at an appropriate time. Second, in-house R&D can help firms to diversify their product line. The importance of this aspect of R&D in developing marketing strengths, solving consumer problems (and creating consumer confidence), and generating spin-off firms in the Canadian forest-product industries is underestimated. In addition to performing these two major functions, in-house R&D groups supply innovations and knowledge, transfer technology from outside and from within the firm, troubleshoot, and attract top people. They also foster technological liaisons with the rest of the R&D system and influence the nature, extent, and effectiveness of R&D conducted by university, government, and cooperative laboratories. Also, R&D groups can identify and apply technologies that increase a firm's competitiveness.³¹

Medium-sized and large forest-product firms in Canada fall into three main categories as R&D performers: each category has potential to establish or increase in-house R&D. First are those that are already investing considerable sums of money, and that may be in a position to establish small, specialized R&D groups to support diversification into, for example, chemicals, energy, or new paper products or possibly to develop expertise in an emerging technology such as biotechnology. Second, there are several firms with R&D groups that are viable but small (less than 15 professional employees) and/or are heavily engaged in service work. These groups could be moved over the next few years to a position on the leading edge of forest-product technology. Third are Canadian-owned forest-product corporations that lack in-house R&D although their size would justify such an investment. Such firms should set up R&D groups to handle both short-term, relatively low-risk ventures and longer-term higher-risk ventures. Firms that have set up new R&D groups have generally done so adjacent to an appropriate manufacturing facility with a distinct "project" in mind (for example, aspen utilization in the case of CanFor)

Smaller firms should establish or increase in-house R&D, through aggressive technology strategies focused on high value-added products, such as remanufactured wood products, treated wood products, specialty papers, and miscellaneous products.

There is little point in suggesting to a foreign-owned subsidiary that it conduct in-house R&D, unless it is for a project that does not duplicate the parent's R&D activities. However, it might be appropriate to encourage Canadian-owned Abitibi-Price to move its woodprocessing R&D group from the United States back to Canada, especially since this laboratory is seeking to develop value-added products (and Abitibi-Price has a large R&D laboratory in Mississauga).

What subjects would be investigated were in-house R&D to be increased would depend upon the specific investment and marketing plans of individual firms. In general, in-house R&D on pulping processes is well represented in the Canadian forest-product industries. By contrast, only MacMillan Bloedel has a major in-house R&D effort in forestry, and R&D in product development, both wood and paper products, has been neglected by Canadian forest-product firms. There are only three in-house R&D groups, for example, that do important
wood-product-related research. In-house R&D on forestry and product development is urgently needed.

To help stimulate R&D in the economy as a whole the federal government offers significant tax incentives. Given that R&D is characterized by indivisibility (high fixed costs), inappropriability (firms investing in R&D can rarely capture all the benefits), and uncertainty (the occurrence of failure) such government support is warranted and should be maintained. In addition, the federal government should seriously consider a proposal by MacMillan Bloedel that essentially would allow a corporation to treat R&D expenditures as tax credits, which can be written off when the firm has net income.³² Other than this no new tax incentives are required. And, forest-product firms are not strong users of existing R&D subsidies. In this industry, technology is normally transferred as part of a large capital investment. Government initiatives that promote innovativeness in investment decision-making can potentially provide a strong incentive to in-house R&D by increasing the level of return on the R&D dollar.

The Role of the Cooperative Laboratories

Many forest-product firms, including firms with and without inhouse R&D, contribute toward financing the cooperative laboratories. These laboratories, notably Feric, Forintek, and Paprican, provide the Canadian forest-product industries with valuable and scarce technological resources. In particular, they offer large pools of highly trained technically qualified people (and particularly in the case of Paprican, of highly trained scientists), who offer complementary technological expertise in wood harvesting (Feric), wood-processing (Forintek), and pulp and paper (Paprican). They are significant components of the technological infrastructure of the Canadian forest-product industries.

This author recommends that industry and government continue to support the activities of Feric, Forintek, and Paprican.

The challenge facing Feric, Forintek, and Paprican is to ensure that their potential to enhance technological change is maximized to the benefit of the Canadian forest-product industries and the Canadian economy.

Clearly, Feric, Forintek and Paprican respond, albeit creatively, to the demands of their public and private membership. But the membership of these organizations, especially Feric and Forintek, is diverse: industry members, for example, vary in terms of size and scope of operations, attitudes toward innovation, and commitment to inhouse R&D. In practice, an important dilemma facing the cooperative research organizations, most notably Feric and Forintek, is how to achieve technological excellence and develop significant innovations given that most of their industry members are so technologically conservative.³³ The industry and government membership of Feric, Forintek, and Paprican need to appreciate more fully the capabilities and limitations of cooperative R&D within the R&D system as a whole (see chapter 4).

Cooperative R&D serves to provide technology that is beyond the means of individual firms and/or that benefits all (or most) firms within the industry. Important functions for Feric, Forintek, and Paprican are to provide long-term applied R&D that can be utilized by in-house programs, to provide a supply of highly skilled workers, to identify and develop process technology that is widely applicable throughout the industry, to facilitate the absorption of available technology, and to develop codes and standards that enhance the competitiveness of the entire industry. As such, cooperative R&D potentially serves all firms in an industry, in one form or another, whether or not firms have in-house R&D. But cooperative R&D does not substitute for in-house programs. In-house R&D typically has a strong development focus and is meant to respond to firm-specific problems and to develop firm-specific competitive advantages whereas cooperative R&D is oriented toward industry-wide problems and industry-wide competitive advantages. However, this distinction is somewhat blurred in practice: the attitudes of individual firms toward cooperative R&D and the demands they make on it depend upon whether or not they invest in in-house R&D.

Within the context of the forestry R&D system, the effectiveness of the cooperative laboratories, particularly Feric and Forintek, is reduced by having to respond to the needs of firms that do not have in-house programs. Some of these firms wrongly perceive cooperative R&D as an alternative to in-house R&D. In the pulp and paper industry the number of in-house programs has been sufficient to encourage Paprican to maintain its traditional emphasis on long-term basic and applied R&D. It is essential for the long-term good of the industry that Paprican maintain such a thrust and not succumb to the view that it can replace in-house efforts.

The R&D focus of Feric and Forintek is more problematic. To live up to their potential, they must increase basic and applied R&D to identify long-term technological needs of, and opportunities for, the wood-harvesting and wood-processing industries of Canada. Such an increase depends upon decisions made by their research program committees. This author therefore recommends, in order to ensure a greater commitment to long-term R&D, that there be better representation of the interests of in-house R&D on the research program committees of Feric and Forintek.

The federal government, as a major source of funds of Feric and Forintek, could encourage appropriate representation. In addition, if Feric and Forintek are to increase long-term R&D they will need to find and absorb more scientists with PhDs. Hiring will have to occur over a number of years; it may well be that Feric and Forintek should increase their sponsorship of graduate training at universities in order to staff themselves (as well as other R&D units) with more highly trained scientists. Government funding may also be required in this endeavour.

In order to address the needs of a diverse membership Paprican, Feric, and Forintek should consider offering a portfolio of different R&D packages from which individual members could choose. This could increase the rate of return on the contributions of individual members to the cooperatives and would allow for more focused discussion of research priorities.

The R&D activities of Feric, Forintek, and Paprican must be directed toward the production, marketing, and investment planning of the Canadian forest-product industries.

This author therefore recommends that the cooperative R&D organizations evaluate how they might support the growing commitment of the forest-product industries to flexibility and value-maximization.

In this regard, Paprican and Forintek's willingness to engage in longterm biotechnology research, including Paprican's recent establishment of a Biotechnology Research Centre, is good news. This kind of research, which is difficult for individual firms to justify, is essential to prepare the industry to take advantage of potentially radical innovations in the decades ahead.³⁴ Similarly, improving the connections between the cooperative laboratories and universities is important because it enlarges the pool of technological resources in Canada directed toward understanding the industry's long-term needs.

In pursuit of flexibility and value-maximization, other initiatives warrant support. For example, Forintek could do more to help the large group of small wood-converting firms that manufacture such items as kitchen cabinets and window frames and the small firms that treat wood. Both these groups sell mostly in Canada and have a limited R&D base, but they do emphasize value-added products for which connections between R&D and marketing are important. In addition, research into wood-based chemicals, which some observers forecast as a major growth area, would be useful to firms contemplating expanding in this direction.

Paprican and Forintek could also play a greater role than they do now in training and transferring MSc and PhD graduates to industry. The need is for industry to generate the demand. To the extent that the Canadian forest-product industries become more committed to flexibility and value-maximization, the demands for science and engineering graduates in production and marketing, as well as R&D, should increase.

In seeking to serve the technological needs of the Canadian forest-product industries Feric, Forintek, and Paprican have necessarily been involved with the equipment supply industry. The links between the cooperative laboratories and equipment suppliers tend to be ad hoc. The lack of strong links between the cooperative laboratories and equipment supply companies stems from the technological conservatism of the latter. Consequently the cooperative R&D laboratories, particularly Feric and Forintek, have often encouraged the importation of "best practice" technology in a way that has reinforced the technologically dependent position of the equipment supply industry. On some occasions, technology developed by the cooperative laboratories has been manufactured by a subsidiary of a foreign firm that subsequently further developed the technology.

This author therefore recommends that the mandates of Feric, Forintek, and Paprican be expanded to include the promotion of the technological strengths of the Canadian equipment supply industry, including the development of "core" firms.

Four suggestions may be offered in this regard. First, Feric, Forintek, and Paprican should seek more formal R&D links with equipment suppliers, in particular, suppliers with Canadian-based R&D groups. Second, the cooperative R&D organizations should ensure that when they commercialize technology in the form of equipment they should do so in such a way as to promote the technological capabilities and industrial strengths of Canadian-based equipment suppliers. In this regard, Paprican's recent experience with licensing Papritection to a Toronto manufacturer should be reviewed carefully with a view to establishing a "model" form of agreement. This licensing agreement incorporated a sliding-scale royalty payment formula that provided for increasingly smaller royalties to be paid by the manufacturer over

a five-year period (and was subsequently renewed). The advantage of Paprican maintaining "control" of the technology in this way is that it provides an incentive to the equipment supplier to develop the technology further.

Third, the cooperative laboratories should consider providing those few equipment supply companies that are capable of contributing toward, and benefiting from, cooperative R&D with a form of membership within the associations. This is not a new idea and, for example, Paprican's Allied Industry Support Program is a step in this direction. It is worth further consideration because the interests of forest-product firms and equipment suppliers should be made more complementary. Fourth, the cooperatives, especially Feric, should aim wherever feasible to establish uniform specifications for proposed technology, for example, silvicultural equipment, and then either specify an appropriate contractor or invite proposals from firms or groups of firms to undertake the development. Contracts should only be awarded to firms or consortia who will develop and manufacture the proposed technology in Canada.

In general, there is a need for the cooperative laboratories to give greater consideration to developing technological strengths among Canadian equipment suppliers. In the field of wood-harvesting technology, for example, observers within forest-product companies and the larger equipment suppliers complain that Feric has passively responded to myriad "local" and often short-term issues, has tended to give too much support to smaller firms lacking in-house R&D programs, and has not dealt effectively with the broad technological questions underlying Canadian woods operations. Certainly, if Feric is to get beyond the fragmented and limited efforts to develop technology for the wood-harvesting operations that characterize the Canadian situation, it will need to adopt a stronger leadership role in identifying technological needs and more aggressively support the leading equipment supply companies.

In-House R&D by Equipment Suppliers

Canada remained dependent on foreign suppliers of capital goods through the 1960s and 1970s. In fact, we are still the world's largest importer on a per capita basis.³⁵

I continue to maintain that Canada's failure to generate a technologically aggressive equipment industry is a failure of tragic proportions.³⁶ The small size and non-innovative nature of Canadian equipment suppliers is a widely known weak link in the Canadian forest-product R&D system.³⁷ The technological weakness of the Canadian equipment supply industry warrants attention. This weakness stems from the narrow concentration on bulk commodities and the conservatism of the forest-product industries, an extremely liberal tariff policy toward imported technology, and an industrial structure characterized by high levels of foreign ownership and small, Canadian-owned firms. Moreover, the activities of the cooperative laboratories, particularly Forintek and Feric, have served to reinforce these conditions by emphasizing adaptive R&D.

Would there be great benefits to the Canadian economy if there were a few large, internationally oriented, highly innovative Canadianbased forest-product equipment supply companies? I believe so. The benefits would be reflected in employment, visible and invisible exports, and in contributions to innovation in the forest-product industries. In this latter respect, for example, forest-product firms would surely benefit from access to highly innovative equipment suppliers who would enjoy an intimate understanding of the technological priorities and problems of the Canadian forest-product industries.

This author therefore recommends that the chief executive officers in domestic equipment supply firms review ways to significantly enhance in-house R&D. In addition this author recommends a concerted effort be made by the private sector and governments to develop "core" firms in the equipment supply industries.

The task will be far from easy. Yet the forest-product industries must become innovative to survive in emerging market conditions and so should be more interested in working closely with suppliers. Moreover, Canada has a massive internal demand for forest-product technology so that there is a continuing economic basis for a large and technologically aggressive equipment supply industry.

A sustained commitment to R&D and innovation in the equipment supply industry only makes sense to firms wishing to grow. Equipment suppliers unable or unwilling to grow will have limited ambitions regarding R&D. Yet surely it is not impossible for two or three firms to develop international aspirations and spheres of operation?

Certainly, there are some growth-oriented technologically aggressive forest-product equipment manufacturers in Canada, and in other sectors large innovative machinery manufacturers have emerged in recent years as a result of entrepreneurial initiative. One example was based on the merger of numerous small companies.³⁸ As an alternative, forest-product firms might consider acquiring an equipment manufacturer; the former would gain technological expertise and the latter guaranteed markets for risky ventures.

The promotion of core firms would not necessarily be detrimental to the interests of small "entrepreneurial" companies. Indeed, the latter may well benefit by serving specialized market niches and by taking advantage of the contracts obtained by the core firms for products made in Canada.

In order to provide an environment within Canada conducive to the promotion of technological strength among equipment suppliers several suggestions may be offered. First, the management of forestproduct companies, especially those involved in R&D, should spend more time and work as closely as possible with equipment suppliers in order to properly identify technological requirements. At present, the emphasis on arm's-length transactions, and in many cases on the "low bid," militates against greater risk-taking by Canadian-based equipment suppliers, especially given their generally small size. Second, the private sector and provincial and federal governments should consider how to prevent foreign-owned firms from continuing to acquire Canadian equipment supply firms and disbanding or absorbing their R&D groups. Such developments are detrimental to Canadian interests. Third, Canadian governments should seriously reconsider the practice of subsidizing modernization schemes that are based on imported technology. As noted earlier, Feric, Forintek, and Paprican could encourage the transfer of technology in several ways that would benefit Canadian-based equipment suppliers, particularly those with in-house R&D programs.

The Canadian forest-product industries need an enriched R&D system characterized by greater in-house effort and by stronger technological liaisons. As a rough guideline it is suggested that in-house R&D by forest-product companies should exceed that of the cooperative laboratories combined by about double the budget and employment levels. The in-house R&D of equipment supply companies should be increased three- or fourfold, including work on paper machinery manufacturing and electronics. Without a stronger in-house effort the other elements of the R&D system will continue to attempt roles for which they are not suited — and innovation will not improve.

Promoting In-House R&D in the Forest-Product Industries

If the Canadian forest-product industries are to promote in-house R&D, then significant changes in attitudes toward innovation will be required. Such changes can only occur if appropriate signals are generated by business and government leaders. The key to such changes, however, rests with business. Innovation involves both R&D and non-R&D components and is as much a managerial problem as an intellectual one. Moreover, product and process development and the transfer of technology is generally best left to industry. Business leaders should establish a commitment to flexibility, value maximization, quality, and innovation in all operations and create a production system in which R&D is more important. Such a commitment also needs to be made publicly in speeches, seminars, and the media. As a practical and symbolic expression of this commitment, business leaders should create a steering committee on technology, comprising leading scientists and engineers, to identify the present and future technological needs of the industry. The first task of this committee could be to produce a detailed study of "innovation needs and the forest-product industries to the year 2000."

If business demonstrates its desire for more in-house R&D then government initiatives may be possible. In particular, federal and provincial governments need to see the forest-product industries within the framework of innovation policy and not as part of a sunset sector as is sometimes the case.³⁹ At the provincial level, the Quebec government recognizes the forest-product industries as an economic planning priority; it has shown a greater appreciation than have other provinces for the importance of local control and for research, development, and innovation. Within Quebec there is an elaborate technological infrastructure upon which to build.

At the federal level several initiatives may be suggested in support of the commitment of business to in-house R&D.

In particular, this author recommends that a review be made of the policies and programs of the Office of the Minister of State (Forestry and Mines) and of the activities of the Department of Industry, Science and Technology (DIST) that relate to the forestproduct industries and the equipment suppliers, chemical suppliers, and engineering consultants.

The Minister of State (Forestry and Mines) needs to raise the public profile of forestry in Canada and to encourage a stonger commitment to forestry management.⁴⁰ In this regard sound proposals for improving the management and innovativeness of Canadian forestry have

recently been articulated.⁴¹ Because timber is the dominant input in forest-product manufacturing processes, planning for forestry and forest-product activities needs to be as thoroughly integrated as possible. In a dynamic environment characterized by rapid changes in markets, technology, and the resource itself, the manner of integration is problematic and reinforces the need to develop an enriched and coherent R&D system.

There is a need to coordinate the Office of the Minister of State (Forestry and Mines)'s interest in how the forest is used with DIST's concerns for forest products. The proposed review should give particular attention to the various types of support available. To provide greater coherence to the current subsidies for industrial expansion, the government should integrate them into a Forest Industries Innovation Fund. This fund should be drawn from within the existing DIST budget and should have several distinct thrusts. It might include the provision of capital cost grants for new or expanded in-house R&D facilities; subsidies for major collaborative R&D programs requiring multidisciplinary research at universities or collaboration between several organizations, for example linking in-house efforts by equipment suppliers; special project funds, for example, to purchase and operate an "experimental mill" that firms could use for prototype work; and low-cost financing for projects and new mills that are extremely innovative. In other words, the Forest Industries Innovation Fund should serve as a stimulus to more fundamental innovation in the development and application of technology in a manner that recognizes the close links that exist between R&D and investment decisions.

The forest-product industries are Canada's most important industrial sector.

This author therefore recommends that the forest-product industries be made the focus of a coordinated innovation strategy. A Forestry and Forest-Products Innovation Committee should be established to consult widely to develop agreement between stakeholders on how to achieve the technological renewal of the forest-product industries. It should also generate specific guidelines on how governments can best contribute to achieving innovation in these industries.

It is imperative that Canadians provide the right climate within which these industries can flourish and continue to provide the lifeline of so many communities across the country. Renewed profitability has opened the options. The opportunity is there. Where now is the foresight, will, and commitment to act?

Notes

1. The Technological Challenge

- 1. Science Council of Canada, Seeds of Renewal: Biotechnology and Canada's Resource Industries (Ottawa: Ministry of Supply and Services, 1985).
- 2. D. Lloyd-Jones, "Lumbermen Blew it with Japan's Builders," The Globe and Mail, Toronto, 8 March 1986, B16.
- 3. A. Hopgood (Enterprises Ltd.), *The Potential for New Technologies in Canada's Forest Sector* (Ottawa: Ministry of State for Science and Technology, 1986).
- 4. J.G. Smith and G. Lessard, Forest Resources Research in Canada, Science Council of Canada, Background Study No. 14 (Ottawa: Information Canada, 1971); O.M. Solandt, Forest Research in Canada (Ottawa: Canadian Forestry Advisory Council, 1979). See also V.N.P. Mathur, R&D in Solid Wood Products: A Review of Non-Federal Government Programs and Activities, Canadian Forestry Service Information Report DDC-X-7, (Ottawa: Department of Environment, 1978).
- 5. Smith and Lessard, op. cit. Solandt, op. cit.
- 6. According to unpublished industry data there are nine forest-product firms in Canada that do R&D: Abitibi-Price, Belkin Paperboard, Canadian International Paper, Consolidated Bathurst, Domtar, Fraser Industries, MacMillan Bloedel, Ontario Paper, and Reed Paper. To this list I added three more: Building Products of Canada, which manufactures pulp and conducts some forest-product R&D but is primarily engaged in (nonforest-related) building material manufacture; St. Anne-Nackawic Pulp and Paper Company, which operates an R&D unit adjacent to its pulp mill in Nackawic; and Canadian Forest Products (CANFOR), which established a new pilot-plant-based R&D group in 1982. The R&D units of Belkin Paperboard and St. Anne-Nackawic Pulp and Paper Company are very small and only barely concerned with conventionally defined R&D. It should be noted that there are firms, such as Xerox Canada, that do not manufacture forest-products but do conduct research on paper and wood properties. Such firms were excluded from this study.
- R. Hayter, "The Evolution and Structure of the Canadian Forest Product Sector: An Assessment of the Role of Foreign Ownership and Control," *Fennia*, 163 (1985): 439-450.
- 8. R. Hayter, "Corporate Strategies and Industrial Change in the Canadian Forest Product Industries," *Geographical Review*, 66 (1976): 216.
- 9. D. Cohen and K. Shannon, *The Next Canadian Economy* (Montreal: Eden Press, 1984).
- 10. W.J. Abernathy, K.N. Clark, and A.M. Kantrow, *Industrial Renaissance* (New York: Basic Books, 1983): 27.
- 11. J.M. Utterbach and W.J. Abernathy, "A Dynamic Model of Process and Product Innovation," Omega, 3 (1975): 639–56; W.J. Abernathy and J.M. Utterbach, "Patterns of Industrial Innovation," Technology Review, June-July (1978): 40–47. As industries mature it is also argued that the nature of investment changes from a "net expansionary mode into a net rationalisation mode" — R. Rothwell and W. Zegweld, Industrial Innovation and Public Policy: Preparing for the 1980s and 1990s (London: Francis Pinter, 1981): 42.

- R. Hayter, "Corporate Strategies and Industrial Change in the Canadian Forest Product Industries," *Geographical Review*, 66 (1976): 209-228;
 R. Hayter, "The Canadian Forest Industries," in I. Wallace (ed.), *Canada's Resource Industries: A Geographical Appraisal* (Ottawa: Carleton University Press, in press).
- 13. Food and Agriculture Organization (FAO), World Forest Products Demand and Supply 1990 and 2000 (Rome: FAO, 1982).
- F.L.C. Reed, "Reshaping Forest Policy," public lecture presented to the Woodward Institute, University of British Columbia, Vancouver, 16 February 1985.
- 15. R. Hohol, "Canadian Pulp and Paper Industry Aims for 50 Per Cent Expansion," *Pulp and Paper Journal*, February 1986: E8-9.
- 16. P.H. Pearse, "Obstacles to Silviculture in Canada," *Forestry Chronicle*, April 1985: 91-96.
- 17. Reed, op. cit.
- 18. Abernathy et al., op. cit. M.J. Piore and C.F. Sabel, *The Second Industrial Divide* (New York: Basic Books, 1985).
- 19. C.R. Silversides, "Mechanized Forestry World War II to the Present," Forestry Chronicle, August 1984: 231–235.
- 20. M.F. Davy, Paper Machine Evolution Since the Year 1920 (Pointe Claire: Paprican, 1984).
- A.J. Cohen, "Technological Change as Historical Process: The Case of the U.S. Pulp and Paper Industry, 1915-40," *Journal of Economic History*, 44 (1984): 775-799.
- 22. See also, S. Hollander, *The Sources of Increased Efficiency: A Study of Dupont Rayon Plants* (Cambridge: MIT Press, 1965).
- 23. Silversides, op. cit.
- R. Schwindt, The Existence and Exercise of Corporate Power: A Case Study of Macmillan Bloedel Limited (Ottawa: Ministry of Supply and Services, 1977): 142-143.
- 25. A. Schuler, "Sawmilling in the 90s: A Look at Factors Mitigating Change," *Canadian Forest Industries*, April 1985: 33–36.
- 26. Schwindt, op. cit., pp. 139-144.
- P. Woodbridge and D. Breck, "High Quality, High Yield Pulps Offer Market Opportunities to Canadian Producers," *Pulp and Paper Canada*, 85 (1984): 18; see also R. Hohol, "Pulping Methods on the Threshold of Change," *Pulp and Paper Journal*, April 1982: 14-16.
- K.E. Šmith, "Cross-direction Control is Still Top Process Automation Trend," Pulp and Paper, February 1985: 72-76.

2. Research and Development

- 1. C.C. Furness, *Research in Industry: Its Organization and Management* (Toronto: Nostrand, 1958).
- 2. Ibid., p. 7.
- 3. Ibid., p. 8.
- 4. C. Freeman, The Economics of Industrial Innovation (London: Penguin, 1974).
- 5. J.P. Hull, *Science and the Canadian Pulp and Paper Industry* 1903–1933, York University, Department of History, unpublished Ph.D. dissertation, 1985.
- 6. A sawmill under construction at Whonnock, British Columbia will be the first in North America to use a certain German technology although 50 such mills already operate in Europe. See "Whonnock plans small-log sawmill," *The Province*, Vancouver, 21 May 1986: 23.

- 7. For example, D.J. Daly, "Weak Links in the Weakest Link," *Canadian Public Policy*, 3 (1979): 307–317
- 8. Schuler, op. cit., p. 5.
- 9. D. Whiteley, "The Cutting Edge," Vancouver Sun, Vancouver, 1 December 1984: E7.
- 10. See J. Clarke, "Forest Labs in Limbo? 'Privatization' Corp. Formed," British Columbia Lumberman, March 1979: 44-53.
- 11. R. Hohol, "Finnish Paper Industry Shifts to Higher Value-added Grades," *Pulp and Paper Journal*, November 1985: 10–12.
- 12. Smith and Lessard, op. cit.
- 13. O.L. Forgacs, "The Role of Industry Research," paper presented at *British Columbia's Future in Science and Research Executive Seminar*, British Columbia Ministry of Education, Science, and Technology, Delta, 25 June 1979.
- 14. See Organization for Economic Cooperation and Development (OECD), The Research System, Vol. 3: Canada, United States, General Conclusions (Paris: OECD, 1974).
- 15. Mr Thorn was the initiator and first technical director of this operation, which, along with the rest of the firm, was taken over by International Paper of New York in the 1920s to create Canadian International Paper.
- 16. These firms included the Price Co., Howard Smith Paper, Dominion Tar and Cellulose, Building Products of Canada, and Fraser, which opened R&D laboratories in the 1930s at Kenogami, Cornwall, Lasalle, Lasalle, and Atholville respectively. After the Second World War they included the predecessor companies of MacMillan Bloedel at Powell River and Nanaimo, the Ontario Paper Company at Thorold, Consolidated Bathurst at Grand-Mère, and, more recently, Belkin Paperboard in Burnaby and St. Anne-Nackawic at Nackawic.
- 17. In the late 1950s Canfor had established a small "planning and development" group as part of its New Westminster plywood operations.
- 18. See Hull, op. cit.
- 19. Another exception to this observation is a building materials laboratory established by Alaska Pine in the 1940s or early 1950s in Vancouver, which was closed down following takeover of Alaska Pine by the American-controlled Rayonier.
- 20. Domtar, for example, closed its laboratory at Lasalle, an industrial suburb of Montreal, and built a new facility at a more spacious site in Senneville. The laboratory at Cornwall meanwhile was maintained. Similarly, Abitibi-Price (as Abitibi) relocated its R&D effort from Sault Ste. Marie to Sheridan Park, Mississauga, and MacMillan Bloedel consolidated its research group at a new facility in Burnaby.
- 21. C.A. Sankey, *PAPRICAN: The First 50 Years* (Pointe Claire: Pulp and Paper Institute of Canada, 1976). See also Hull, op. cit.
- 22. I.A. Litvak, Canadian Trade Associations and the Promotion and Diffusion of Innovations, Technical Innovation Studies Programme Research Report (Ottawa: Department of Regional Industrial Expansion, 1985).
- 23. Sector Task Force, *The Canadian Forest Products Industry* (Ottawa: Department of Industry, Trade and Commerce, 1978). Canada, Government of, *Response of the Federal Government of the Consultative Task Force on the Canadian Forest Products Industry* (Ottawa: Department of Industry, Trade and Commerce, 1979).
- See D. Dingeldein, "One Very Weak Link," Canadian Research, November 1978: 5; and R.W. Kennedy, "Research: A Shortfall, but Who is Really to Blame?" Canadian Pulp and Paper Industry, January 1979: 18.

- 25. Litvak, op. cit., pp. 45-46.
- 26. The Western Forest Products Laboratories' interests in pulping processes have been taken over by Paprican at its new facility in British Columbia.
- 27. Interestingly, one leading firm suggested that although Scandinavian firms took the lead in the development of wood-processing equipment in the 1970s, especially with respect to the incorporation of microelectronics, their rate of technological advancement has levelled off because they are concentrating on recapturing costs by selling existing products. According to this firm, there is now an opportunity to leapfrog the achievements of Scandinavian firms.
- 28. J. Sorenson, "Innovative Rim Saw to Replace Bandmills," Canadian Forest Industries, May 1984: 12-14.
- 29. P. MacDonald, "Computer Applications Unlimited," British Columbia Lumberman, April 1984: 30-31.
- 30. See Smith and Lessard, op. cit., and Solandt, op. cit.
- 31. Smith and Lessard, op. cit., p. 65.
- 32. D.E. Barron, J.H. Smithy, K.L. Campbell, and J.P. Martel, *Forest Management Expenditures in Canada* 1977–1983, a joint report of the Canadian Pulp and Paper Association and the Great Lakes Forest Centre (Montreal: Canadian Pulp and Paper Association, 1986).
- 33. R. Hayter, "Research and Development in the Canadian Forest Product Sector — Another Weak Link?" *Canadian Geographer* 26 (1982): 256-263; Solandt, op. cit.
- 34. Barron et al., op. cit., p. 6.
- 35. See Solandt, op. cit. For example, a group of researchers in the biology department at Simon Fraser University has recently pioneered techniques to control pests that perennially inflict significant damage on British Columbia's forests.
- 36. In fact, the expertise of the engineering consulting community in Canada on forest-product technology is such that there is a global demand for its advice about choice of technology, transfer of technology, and mill design and layout.
- 37. Recently, for example, Feric and Paprican, in association with Hymac, a pulping machinery manufacturer, joined together to develop the Paprifer, which is a process designed to upgrade chips from logging residues, full trees, and otherwise unmerchantable material.
- 38. Smith and Lessard, op. cit.
- 39. Solandt, op. cit.
- 40. Ibid.

3. The R&D System and How It Works

- 1. Silversides, op. cit., p. 232.
- 2. Ibid., p. 233.
- 3. D.A. Tillman, Forest Products: Advanced Technologies and Economic Analyses (New York: Academic Press, 1985): 95.
- 4. For example, Schwindt, op. cit., was able to identify the origins of 40 major and 34 minor innovations introduced into Canada between 1950 and 1976. Of these 27 and 17 respectively originated with equipment manufacturers around the globe.
- 5. R. Hohol, "Pulping Methods on the Threshold of Change," Pulp and Paper *Journal*, April 1982: 14–16.
- 6. Sankey, op. cit., p. 111.

- P.G. Mellgren and E. Heidersdorf, *The Use of High Flotation Tires for Skidding* in Wet and/or Steep Terrain, Technical Report No. TR-57 (Pointe Claire: Feric, 1984).
- 8. Ibid., pp. 44-45.
- 9. J.C. Salesky, "The Sawmill Improvement Programme Instant Forestry at Work," Forest Products Journal, 35 (1985): 6.
- 10. Forintek, "Forintek's Lumber Size Program," Forintek Review, March 1985: 3-4.
- 11. E.B. Kirbach, "Methods and Equipment Update for Stellite Tipping," *Canadian Forest Industries*, January 1986: B22-23.
- 12. P. MacDonald, "Stellite to Become Standard on Mill Cutting Equipment," British Columbia Lumberman, October 1984: 10-11.
- 13. J. Sorenson, "Untensioned Saw Blade Cuts at High Speeds," Canadian Forest Industries, May 1984: 16-18.
- 14. Forintek, "Major Project in Lumber Drying Technology," Forintek Review, February 1985: 6-7.
- 15. Forintek, "The Forintek Culture Collection of Micro-organisms," Forintek Review, March 1985: 5-6.
- 16. For example, S. Globerman, "New Technology Adoption in the Canadian Paper Industry," *Industrial Organization Review*, 4 (1976): 5–12.
- 17. This was revealed by Bengsten et al.'s recent discussion of the diffusion of structural particleboard in North America: D.N. Bengsten, H.M. Gregersen, and J. Haygreen, "Seesawing Across the 49th Parallel: the International Diffusion of a Wood-based Technology," paper presented at the 1986 Forest History Society Conference, Vancouver, 8–11 October 1986.
- 18. Tillman, op. cit.
- 19. See J. Cotter, "The Challenge is in Learning How to Apply New Technology," *Pulp and Paper Journal*, September 1982b: 10-11; S.R. Dartt, "Microprocessor-based Control Systems — Where Are We Going? *Pulp and Paper*, February 1986: 71-74; O.K. Fadum, "Mill-wide Automation: A Look at What's Available," *Pulp and Paper Journal*, April 1984: 12-20; Smith, op. cit.
- See, for example, Science Council of Canada, Seeds of Renewal: Biotechnology and Canada's Resource Industries (Ottawa: Ministry of Supply and Services, 1985) and P. Winter, "A Forest in the Hand," Science Dimension, June 1985: 10–13.
- 21. Tillman, op. cit., Hopgood, op. cit.
- 22. Tillman, op. cit., pp. 148-176.
- 23. Ibid., p. 154.
- 24. See R. Hohol, "Pulping Methods on the Threshold of Change," Pulp and Paper, April 1982: 14-16; R.A. Leask, "TMP Trend is Still Towards Higher Capacity Refiners," Pulp and Paper Canada, March 1984: 14-15; M. Vaillancourt, "Putting a Tree in Your Tank: Breaking Wood Down to Alcohol," Science Dimension, 4 (1984): 19-24; Woodbridge and Breck, op. cit.
- 25. Tillman, op. cit., pp. 155-176.
- 26. Ibid., pp. 197-215.
- 27. Ibid., pp. 221-267.
- 28. Ibid., Hopgood, op. cit.

4. Technological Capability and Technological Liaisons: An Assessment

1. J.N.H. Britton and J.M. Gilmour, The Weakest Link: A Technological Perspective

on Canadian Industrial Underdevelopment, Science Council of Canada, Background Study No. 43 (Ottawa: Minister of Supply and Services, 1978).

- R. Hayter, "Research and Development in the Canadian Forest Product Sector — Another Weak Link?" *Canadian Geographer*, 26 (1982): 256-263; R. Hayter, "The Evolution and Structure of the Canadian Forest Product Sector: An Assessment of the Role of Foreign Ownership and Control," *Fennia*, 163 (1985): 439-450.
- 3. The information was obtained, first, from directories. See Cattell Press, Industrial Research Laboratories of the United States (New York: Bowker, 1977) and A.M. Palmer, Research Centers Directory (Detroit: Gale Research Company, 1977). Second, data were obtained by telephone from R&D organizations not listed in the directories. See R. Hayter, "Research and Development in the Canadian Forest Product Sector — Another Weak Link?" Canadian Geographer, 26 (1982): 256-263.
- 4. J. Kalish, "PPI's Top 100," Pulp and Paper Industry, September 1977: 89-96.
- 5. P. Hanel, *La technologie et les exportations canadiennes du matériel pour la filière bois-papier* (Montréal: L'Institut de recherches politiques, 1985).
- 6. Ibid., p. 57.
- 7. See Business Week, "R&D Scoreboard," Business Week, 23 June 1985: 102.
- 8. Business Week, "R&D Scoreboard," Business Week, 23 June 1985: 139-140.
- Hanel, op.cit. See also R. Hayter, *Technological Capability in the Forest Product Sector of British Columbia: An Exploratory Inquiry*, Discussion Paper No. 13 (Burnaby: Department of Geography, Simon Fraser University, 1981): 14-18.
- 10. Hanel, op. cit., p. 66.
- 11. R. Hayter, Technological Capability in the Forest Product Sector of British Columbia: An Exploratory Inquiry, Discussion Paper No. 13 (Burnaby: Department of Geography, Simon Fraser University, 1981).
- 12. Hanel, op. cit.
- 13. J. Sorenson, "Steep Slope Slashers Debut on West Coast," Canadian Forest Industries, May 1984: 14–17.
- 14. Canadian Forest Industries, "Italian Manufacturers Target Canadian Mills," Canadian Forest Industries, October 1984: 29.
- 15. R. Hayter, Technological Capability in the Forest Product Sector of British Columbia: An Exploratory Inquiry, Discussion Paper No. 13 (Burnaby: Department of Geography, Simon Fraser University, 1981).
- 16. J. Raumolin, "The Impact of Forest Sector on Economic Development in Finland and Eastern Canada," *Fennia*, 163 (1985): 395-431.
- 17. Indeed, such patterns with respect to the Canadian economy as a whole were long ago observed by H. Marshall, F.A. Southard, and K.W. Taylor, *Canadian–American Industry: A Study in International Investment* (Toronto: The Ryerson Press, 1936): 281–282.
- R. Hayter, Technological Capability in the Forest Product Sector of British Columbia: An Exploratory Inquiry, Discussion Paper No. 13 (Burnaby: Department of Geography, Simon Fraser University, 1981): 61.
- 19. Columbia Cellulose, which provided the only internal source of dissolving pulp to its parent company, employed about 90 people in the mid-1960s at its then new Vancouver laboratory whose R&D on pulping processes was closely integrated with the parent's R&D in New York. Following corporate losses, however, this facility was cut back considerably and since 1972 it has hived off to form the basis of a small, private company. Ontario Paper, whose parent is the Chicago Tribune a nonforest product firm has a small R&D group in Thorold. In recent years

this R&D facility has become even smaller. Consequently, since the mid-1970s among American-owned subsidiaries only Canadian International Paper has operated a major forest-products laboratory in Canada. This facility had its roots in a Canadian firm that CIP acquired in the 1920s. Moreover, since the late 1960s CIP's R&D efforts have become progressively smaller, while the parent company, International Paper, has built up a new facility in the U.S. (And in 1983 IP sold CIP to Canadian Pacific for about \$1 billion.)

- 20. Canada, Government of, *Foreign-direct Investment in Canada* (Ottawa: Information Canada, 1972): 405.
- P.H. Pearse, *Timber Rights and Forest Policy in British Columbia* (Victoria: Report of the Royal Commission of Forest Resources, 1976); Kates, Peat and Marwick and Co., *Foreign Ownership and Forest Based Industries* (Toronto, 1973).
- 22. Britton and Gilmour, op. cit.; R. Hayter, "Truncation, the International Firm and Regional Policy," *Area*, 14 (1982): 277-282.
- 23. Freeman, op. cit.
- 24. R. Hayter, "Patterns of Entry and the Role of Foreign-controlled Investments in the Forest Product Sector of British Columbia," *Tijdschrift voor Economische en Sociale Geografie*, 72 (1981): 99-113.
- 25. Hanel, op. cit.
- 26. Ibid.
- 27. Cordell and Gilmour (1976) have described the problems in transferring technology from government laboratories to the manufacturing sector and these problems also obtain in the forest-product sector. See A.J. Cordell and J.M. Gilmour, *The Role and Function of Government Laboratories in the Transfer of Technology to the Manufacturing Sector*, Science Council of Canada, Background Study 35 (Ottawa: Information Canada, 1976); Canada, Government of, *Response of the Federal Government to the Consultative Task Force on the Canadian Forest Product Industry* (Ottawa: Department of Industry, Trade and Commerce, 1979); and Sector Task Force, *The Canadian Forest Product Industry*, Trade and Commerce, 1978).
- 28. R. Hohol, "A Frank Conversation with MB's Research Chief," Pulp and Paper Journal, March 1983: 40.
- 29. Ibid., 134-141.
- W.M. Cohen and D.C. Mowery, "Firm Heterogeneity and R&D: An Agenda for Research," in B. Bozeman, M. Crow and A. Link (eds.), Strategic Management for R&D (Lexton: D.C. Heath, 1984): 197-232; E. Mansfield, "R&D and Innovation: Some Empirical Findings," in Z. Griliches (ed.), R&D, Patents and Productivity (Cambridge: National Bureau of Economic Research, 1984): 127-154.
- 31. Cohen and Mowery, op. cit.
- 32. B.R. Williams, "The Basis of Science Policy in Market Economies," in B.R. Williams, *Science and Technology in Economic Growth* (New York: Wiley, 1973): 416-431.
- 33. Cohen and Mowery, op. cit., p. 109; see also R.R. Nelson, "Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures," *Journal of Economic Literature*, 19 (1981): 1029–1064. Cohen and Mowery (p. 118) say that in-house R&D increases a firm's "unique technological and organizational abilities." Gort and Klepper (1982) state that the knowledge that it generates is transferable only at some cost and over some time period or is non-transferable and contributes to a firm's

R&D related "organizational capital." In their view, the level and composition of a firm's R&D spending reflects its distinctive technological, marketing, and financial expertise, the particular problems and opportunities that arise from its location, its market experience, its internal structure, and its long-term objectives. M. Gort and S. Klepper, "Time Paths in the Diffusion of Innovations," *Economic Journal*, 92 (1982): 630–653.

- 34. J.C. Finkbeiner and O.L. Forgacs, *Recommended Amendment to the Income Tax Act to Reinforce Industrial Research and Development in Canada in Troubled Times* (Vancouver: MacMillan Bloedel, 1982).
- 35. Smith and Lessard, op. cit., Solandt, op. cit.
- 36. L. Nasbeth, "The Diffusion of Innovations in Swedish Industry," in Williams, op. cit., 256-280.

5. Modernization and the Choice of Machinery and Equipment

- 1. The equipment purchases by the forest-product industry that do not involve technology that is new to the firm or the industry reflect routine "replacement" decisions, and rarely involve large expenditures. See P. Marchak, *Green Gold: The Forest Industry in British Columbia* (Vancouver: University of British Columbia, 1982).
- 2. P. Woodbridge, "New Growth Opportunities Depend on Two Key Factors," Pulp and Paper Journal, May 1984: 23-27.
- 3. Ibid., p. 23.
- 4. H. Enchin, "Forest Products," *The Globe and Mail*, Report on Business 1000, June 1984: 34.
- 5. Ibid.
- 6. F.J. Anderson and N.C. Bonsor, *The Ontario Pulp and Paper Industry: A Regional Profitability Analysis* (Toronto: Ontario Economic Council, 1985).
- 7. Ibid.
- 8. The process began in 1972 with the replacement of two paper machines at another Quebec location in a mill where the paper machines were small and relatively cheap to replace. The paper machine chosen was made in Canada by a then Canadian-owned firm.
- 9. R. Hayter, "Labour Supply and Resource-based Manufacturing in Isolated Communities: The Experience of Pulp and Paper Mills in North Central British Columbia," *Geoforum*, 10 (1979): 163–177.
- 10. C.H. Kepner and B.B. Tregoe, *The Rational Manager* (New York: McGraw-Hill, 1965).
- 11. Silversides, op. cit., p. 234.
- 12. Ibid.
- 13. W.E.G. Salter, *Productivity and Technical Change* (Cambridge: Cambridge University Press, 1966).
- 14. A more effective employment policy, which would also have had positive implications for technological capability, might have been to support the equipment supply industry rather than the highly capital-intensive pulp and paper industry.

6. Promoting In-House R&D in the Canadian Forest-Product Industries

- 1. R. Reich, "Beyond Free Trade," Foreign Affairs, 60 (1983): 852-881.
- 2. R. Kuttner, *The Economic Illusion: False Choices Between Prosperity and Social Justice* (Boston: Houghton Mifflin, 1984).

- 3. K. Noble, "Forest Industry Urged to Bail Itself Out," *The Globe and Mail*, Toronto, 14 March 1986: B7.
- 4. To a significant degree Canada's forest-product industries have always competed in a free trade environment. This negates the argument that free trade would promote innovation.
- 5. Reich, op. cit.
- 6. R. Hayter, "Corporate Strategies and Industrial Change in the Canadian Forest Product Industries," *Geographical Review*, 66 (1976): 209-228.
- 7. F. Longo, Industrial R&D and Productivity in Canada (Ottawa: Science Council of Canada, 1984).
- 8. C. Black, "Concentration of Ownership by Canada's Bigger Capitalists is the Only Firebreak Against Wholesale Foreign Purchases," *Report on Business Magazine*, Toronto, February 1986, 97-100.
- 9. David Vice as quoted by R. Anderson, "Firms Must React Quickly to Change," *The Globe and Mail*, 13 May 1986, B21.
- 10. J.N.H. Britton, "Industrial Policy in Canada and Australia: Technological Change and Small Firms," in R. Hayter and P.D. Wilde (eds.), *Industrial Transformation and Challenge in Australia and Canada* (Ottawa: Carleton University Press, in press).
- 11. G. Krumme, "Views in Industrial Location Decision Theory," in J. Rees, G.J.D. Hewings, and H.A. Stafford (eds.), *Industrial Location and Regional Systems* (London: Croom Helm, 1981): 115.
- 12. R. Hayter, "Corporate Strategies and Industrial Change in the Canadian Forest Product Industries," *Geographical Review*, 66 (1976): 209–228; Tillman, op. cit., p. 25.
- 13. Tillman, op. cit., p. 185.
- 14. Technological advance is not necessarily associated with increases in scale. For example, some new pulping processes have relatively low economies of scale thresholds.
- 15. Krumme, op. cit.
- O.L. Forgacs, "Forintek Plays Key Role in R&D System," Forintek Review, July/August (1986): 6-7; K.A. French, President, Forintek, "Progress Through Partnership," speech to the Canadian Council of Forest Ministers, Fredericton, 22 July 1986.
- 17. Marchak, op. cit.; Schuler, op. cit.
- O.L. Forgacs, "Forintek Plays Key Role in R&D System," Forintek Review, July/August (1986): 6.
- 19. P.R. Richardson, "Winning Through Technology," Canadian Business Review, Summer 1986: 46.
- 20. Ibid., p. 49.
- 21. J. McAllister, "Ambitious Human Resources Program Key To Kenora Modernization Success," *Pulp and Paper Journal*, February 1986: 56–57.
- 22. B. Westergaard, "MB's Innovative Quality Program Saves \$28m in Just Two Years," *Pulp and Paper Journal*, March 1986: 22-23.
- Sector Task Force, op. cit.; O.L. Forgacs, "Forintek Plays Key Role in R&D System," Forintek Review, July/August (1986): 6–7; French, op. cit.
- For example, J. Cotter, "Facing the Future with R&D," Pulp and Paper Journal, May 1982: 46-49; Hanel, op. cit; Marchak, op. cit; G. Rooden, "R&D Can Give a Company That All Important Technical Edge," Pulp and Paper, May 1984: 11-13; Science Council of Canada, Canada's Threatened Forests (Ottawa: Science Council of Canada, 1983); Smith and Lessard, op. cit.; T. Whitney, "R&D Budget Cuts Damage Forest Industries Position,"

Canadian Research, November 1978: 32-34; Woodbridge, Reed and Associates Ltd., British Columbia's Forest Products Industry: Constraints to Growth, prepared for the Ministry of State for Economic and Regional Development (Vancouver, 1984).

- 25. Sector Task Force, op. cit., p. 9.
- 26. Canada, Government of, *Technology Diffusion in Canada: Myths and Realities* (Ottawa: Ministry of State, Science and Technology, 1986).
- 27. Hanel, op. cit.
- 28. Silversides, op. cit.
- 29. D. Bengsten, "Aggregate Returns to Lumber and Wood Products Research: An Index Number Approach," in Forestry Research Evaluation: Current Progress, Future Directions, proceedings of the Forestry Research Evaluation Workshop, 10-12 August 1984, St. Paul, Minnesota, compiled by C.D. Risbrudt and P.J. Jakes (USDA and Forest Service), General Technical Report NC-104, 1984: 62-68; H. Gregersen, "The University of Minnesota Research Programme," ibid., pp. 31-33; R. Westgate, "Returns to Investment in Forestry Research: The Case of Containerized Forest Tree Seedlings," ibid., pp. 117-120; Tillman, op. cit; see also Forintek, Ready for Excellence: A Program Review 1982-86 (Vancouver: Forintek, 1986): 16.
- E. Mansfield, J. Rapport, J. Romeo, E. Villani, S. Wagner, and F. Husic, *The* Production and Application of New Industrial Technology (New York: Norton, 1979): 189.
- 31. Richardson, op. cit., p. 45.
- 32. Finkbeiner and Forgacs, op. cit.
- 33. O. Forgacs, "Forintek Plays Key Role in R&D System," Forintek Review, July/August 1986: 7.
- 34. L. Jurasek and M.G. Paice, *Biotechnology in the Pulp and Paper Industry*, manuscript report (Ottawa: Science Council of Canada, 1984).
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