Status of Forest Sector Research and Development in Canada

Clark S. Binkley
Dean
Faculty of Forestry
University of British Columbia
Vancouver, B.C. V6T 1Z4

(604) 822-2467 tel
(604) 822-8645 fax
binkley@unixg.ubc.ca

and

Otto L. Forgacs
Principal
Otto Forgacs Consultants
1843 Acadia Road
Vancouver, B.C. V6T 1R2

(604) 224-5861 tel
(604) 224-1128 fax
oforgacs@istar.ca

26 June 1997

Résumé. L'activité de recherche-développement (R-D) dans le secteur canadien des forêts (y compris les travaux des gouvernements, de l'industrie, des instituts de recherche et des universités) est demeurée essentiellement statique ces dix dernières années (augmentation réelle de 0.6% par année entre 1987 et 1997), même si l'industrie éprouve un besoin concurrentiel et sociétal plus grand en produits à marge bénéficiaire accrue. Au pays, les dépenses de R-D forestière de toutes sources représentent seulement 0,4 % environ de la valeur des expéditions, chiffre qui se situe au bas de l'échelle pour le secteur des biens et accuse du retard par rapport au rendement obtenu dans la plupart des pays à qui le Canada fait concurrence. L'appui fédéral à la R-D forestière a diminué, en termes absolus comme en pourcentage du total. Les sommes internes engagées par les entreprises dans la R-D semblent à la baisse, qu'elles soient calculées en fonction des dépenses ou du nombre de personnes affectées à la tâche. Dans la province, les dépenses de R-D ont augmenté, grâce exclusivement au programme de recherche de Forest Renewal BC. La médiocrité des données sur la R-D dans le secteur forestier au Canada nous indique bien le peu d'importance que les gestionnaires des secteurs public et privé accordent à l'innovation comme outil stratégique principal pour le secteur. Il faut surtout craindre le déclin majeur de la R-D dans le secteur des produits du bois, où la hausse des coûts, alliée aux pressions engendrées par les produits concurrentiels, donne une importance toute particulière au progrès technologique. Les perspectives concernant la demande mondiale de produits forestiers semblent bonnes, mais la participation du Canada à la croissance du secteur semble dépendre de sa capacité d'innover. Le gouvernement joue un rôle prépondérant dans la R-D forestière : (i) en offrant du soutien direct quand les questions sont d'intérêt public et (ii) en créant un climat économique et social propice à l'obtention d'un taux de rendement raisonnable sur les sommes que l'entreprise privée doit investir dans la technologie et l'équipement.

Abstract. After an initial increase between 1982 and 1987, research and development (R&D) activity in the Canadian forest sector (including that performed by government, industry, research institutes, and universities) has remained essentially static (increase of 0.6%/yr between 1987 and 1997), despite the competitive need and societal desires for the industry to move to higher margin products. Totalled across all sources, forest sector R&D spending in Canada equals only about 0.4% of the value of shipments, a figure that is at the low end of the range characteristic of commodity businesses. Federal support of forest sector R&D has declined both in absolute terms and as a percent of the total. The aggregate intramural R&D spending by the companies appears to be in decline, whether measured by expenditures or the number of people employed in this function. The research program of Forest Renewal BC accounts for the entire growth in provincial expenditures on forest sector R&D. Of particular concern is the low and declining level of R&D activity in the wood products sector, where a combination of rising costs and pressure from competitive products make technological innovation particularly important. While the outlook for world demand for forest products is favourable, Canada’s participation in this growth appears dependent on technological innovation. Government plays a major role in (i) directly supporting those areas of R&D with substantial public-goods aspects, and (ii) creating an economic and social climate in which the required private investments in technology and equipment can yield an acceptable return.

1. Introduction

Throughout this century the forest products industry has contributed more wealth to Canada than any other industrial sector. In recent years, forest products exports have exceeded the total of the next three leading industries. Our forest sector makes possible a material standard of living in Canada that is among the highest in the world.

Global prospects for the forest products industry appear quite favourable (Solberg, 1996). As the large populations in Asia, South America and Eastern Europe emerge from relative poverty, demand will increase for housing (and therefore solid wood products), for paper packaging and for paper used as a means of communications. However, the Canadian industry may be poorly positioned to participate in this growth.

During the last several decades, many factors have combined to erode the international competitiveness of Canada's forest sector. New competitors using low-cost plantation-grown timber resources have entered the field. Canadian wood costs are rising due to longer hauls, more difficult logging terrain, rapidly increasing stumpage fees levied by government and increasingly stringent forest practice regulations. In many locations, allowable annual cuts are falling as forest land is devoted to other uses and as these losses of commercial timberland are not offset by increased silvicultural investments or technical innovation. Similarly, new regulations such as the Forest Practices Code of B.C. have added significant new costs. Power costs are rising as governments increase their revenue demands on Crown power corporations. Each of these factors reduces sector profitability and its capacity to attract the capital needed for the modernization and environmental improvements required to sustain competitive positions.

In this respect, the developing financial profile of the Canadian forest industry is extremely troubling. For example, over the past two business cycles, the average return on capital for the British Columbia industry has been a mere 6.7%, much lower than the average cost of capital, estimated to be at least 11% (MacCallum, 1997). The industry's performance in other regions of the country is no better. While forest products companies in other regions of the world also have difficulty earning the hurdle rate, their average returns are substantially higher than those of Canadian forest products companies. Companies whose average earnings over the business cycle do not match the cost of capital are on a downhill spiral of disinvestment feeding reduced profitability, which in turn precludes the capital investments needed to restore profitability. Unless, of course, the factors underlying poor performance are reversed.

Technological change is one of the most powerful factors available to do so. In fact, ignoring the costs directly influenced by governments (e.g. stumpage, power or regulatory costs), technological change is the *only* means available to sustain a competitive position while continuing to pay the desirably high wages which characterize the Canadian forest products industry. Technological change is needed because of

- changing forest products markets, especially increased competition from within the global forest products industry;
- market challenges from *other* industries, such as steel and plastics in the case of wood products and packaging, and electronic media in the case of pulp and paper products; and
- continuing societal demands for improved environmental performance in the industry.

These factors take on added currency in a world where the age of the Canadian industry's physical plant, especially in the pulp and paper sector, is old compared with that of the competition (many of the paper machines running in Canada today were installed prior to World War II). Mandatory investments

in pollution control have sopped up much of the internally available capital. While the need to install leading-edge equipment is well recognized by the industry, Canadian cost structures combined with likely product-pricing scenarios frequently produce unacceptable anticipated returns. As a result, the needed capital investments simply are not made.

The technological changes likely to make a difference to the Canadian forest sector are those that will re-establish competitive advantages, rather than those that merely help the industry 'catch-up' to the favourable circumstances of our competitors. To do so, the Canadian industry needs not just new technology, but *innovative* technology specifically tailored to Canadian circumstance — fibre types, operating conditions and input costs. And innovative technology arises out of research and development (R&D).[1]

This paper takes stock of the levels and trends in R&D activity in the Canadian forest sector in industry, universities and government from 1982 to 1997. While a review of past activities provides an insight into the effectiveness of past strategies and policies, the need for R&D stems from an assessment of future needs, and more specifically, from an assessment of the kind of forest sector Canada wishes to have in the next century. Charles Kettering (the famous technical chief of General Motors from 1916 to 1947) put it well: "Research is what you do when you know that you cannot go on doing things tomorrow the way you are doing them today, and you don't know what to do."

While the data in this paper are about the past, we interpret them not as a mere statistical history, but rather in light of the national and international challenges to Canadian forest practices and industrial performance. The first section below lays out our methodology for assembling the data. The second section reviews overall trends in total expenditures, and breaks out the trends into industry and governmental expenditures. The third section puts these trends into a strategic context, arguing that socially desired changes in the sector are unlikely to occur with the current pattern of diffuse-focused, low-level R&D expenditures. We conclude with a few positive suggestions about how to change this undesirable state of affairs.

2. Definitions and Methodology

No one organization regularly collects and analyzes data on R&D activities or expenditures for the Canadian forest sector (this fact alone signals the comparatively low level of importance the subject carries for public and private policy makers.) Hence, to assess the status and trends in forest sector R&D, it is necessary to assemble data from a variety of sources, both primary and secondary. This requires both clear definitions of "forest sector" and of "research and development." This section provides our definitions and describes our data collection efforts.

Definition of the Forest Sector

Most broadly defined, the Canadian forest sector includes forests, forest-products manufacturing facilities (e.g. logging enterprises, sawmills, pulpmills, secondary manufacturing industries), the firms which supply inputs for the manufacturing firms, equipment suppliers, the transportation sector dependent on the industry and the so-called minor forest products such as mushroom and salal collection. One would logically include forested parks in this definition since their existence is, at

[1]An example of what can be done is the recent conversion by MacMillan Bloedel (MB) of a paper-machine at Port Alberni to make coated paper, for about 50% of the capital cost of conventional technology. This development was the result of a joint program of development based largely on Valmet machinery and MB process technology (McCaig and Harala, 1997).

least in part, predicated on the need to offset putative losses of biodiversity in areas that are used for industrial purposes. Such a suitably broad definition covers numerous ministries of provincial and federal governments, many industrial sectors and a wide range of research institutes and university departments. Unfortunately, the data on R&D activities in Canada are generally poor in scope and depth, and no central statistical agencies assembles information on this appropriately comprehensive definition of the sector.

For the purposes of this paper, we take a more restricted definition to focus on the industrial activities of the forest sector, and only a limited set of those. For our purposes, the Canadian forest sector consists of three principal components — the forests, wood products manufacturing and the pulp and paper industry. The latter two each currently generate about the same value of annual shipments, and the industrial value of the forests themselves is subsumed within the industry shipment data. While technologically distinct, the two industrial sectors are closely intertwined: they share common raw material sources, sawmill by-products provide much of the feedstock for pulp and paper, and, as a consequence, many operating units are managed under joint ownership.

The Canadian industry depends critically on its ability to harvest primary, indigenous forests at costs which compare favorably with those of other wood-producing regions. While small quantities of wood are imported from other countries, a Canadian forest products industry based on significant amounts of imported wood is not likely to survive. Although considerable attention has recently been paid to the use of agricultural residues for the pulp and paper industry, formidable technical and business challenges limit the application of these fibre sources. Any review of the state of science and technology in the Canadian forest products industry logically begins by considering forest resources.

Circumstances have changed quite rapidly in the last several decades. For most of its history, the forest products industry throughout the world has depended on natural forests. Only during this century have plantations become an important source of timber supply, and the pace of this transition has recently accelerated. Such countries as New Zealand and Brazil have become prominent in international forest products markets using intensively managed plantations alone as a source of timber supply. Some other countries (e.g. Argentina, Indonesia and Thailand) harbour plantation estates that will soon support internationally competitive wood products manufacturing facilities. Combined with the environmental problems sometimes associated with timber extraction in primary forests, the low cost and uniform fibre characteristics of plantations comprise a potent threat to Canada's position in international markets (Marchak, 1996). The world no longer has to beat a path to the Canadian door for its fibre supply.

Provincial governments in Canada — who control most of the country's forest land — have generally adopted a policy of managing natural forests with a very low level of silvicultural inputs. The multiple benefits of forests are provided intertwined in the context of the industrial operations (Booth *et al.,* 1994). While keeping input costs low, this policy creates some special problems for Canada. In particular, it severely limits the capacity to employ technological innovation as a means to increase forest yields to offset set-asides for parks, ecologically sensitive areas and other socially desirable purposes (Binkley, 1997).

In addition to forests, our review also covers those aspects of the forest products industry involved in harvesting, manufacturing and marketing the forest resource at various levels of conversion. While Canada has an enviable record in the science and technology associated with forest products

manufacturing, these innovations have not always been rapidly adopted in the domestic industry.[2] Furthermore, great advances have been made elsewhere in the world (e.g. eucalyptus pulping in Brazil; radiata pine processing in New Zealand) by simultaneously designing silvicultural regimes, products and production processes. In a country such as Canada where the forest resource in largely owned independently of the manufacturing facilities, the gains from such integrated development are largely unavailable to the industry.

Apart from wood, the forest products industry consumes a large number of other inputs, especially electrical energy, and chemicals (ranging from those used to enhance forest productivity, to adhesive resins, pulping and bleaching chemicals, mineral fillers, and coatings) and a myriad of other materials. The forest industry is also highly capital intensive, and depends at every stage on large-scale equip-ment, from harvesting machines and vehicles to sawmilling and fibre processing and converting machines, all controlled by a profusion of process control equipment and technologies.

The suppliers of these inputs and equipment contribute their own R&D to the state of the forest products industry, and it can be argued that they are a part of it. The Canadian forest sector supports a small cadre of these companies, including such firms as Newnes in the area of mill optimization and control, Madill in cable logging, CAE in pulp screening and composites, and Hymac in refining. For the purpose of this paper, however, suppliers have *not* been included. This omission is due to (i) the difficulty in identifying the universe of firms to sample, and (ii) the reluctance of these firms initially contacted to provide data to us, on grounds that revealing such information might compromise their competitive positions.

Definition of Research and Development

Despite the appeal of Kettering's definition, for the purpose of this study, data were collected using the Revenue Canada's narrow definition used for determining the eligibility of expenses claimed under sections 31 and 31.1 of the Income Tax Act. Under the Act, "Scientific Research and Experi-mental Development" essentially requires that:

- at the outset of the activity, the outcome is technologically uncertain;
- the activity is carried out in a planned and systematic way; and
- the activity generates information which advances our understanding of scientific relations or technologies.

This definition is generally compatible with the data that are available through Statistics Canada and the various R&D performing organizations.

R&D under this definition is not synonymous with "science and technology" (S&T), but is rather one component of the overall requirements for successful industrial innovation. A company that successfully conducts R&D may lack the technical and management skills in its mills, or may not possess the corporate culture or the financial resources needed to exploit the commercial rewards that are offered by innovative technological opportunities.

[2]Canadian scientists have won four of the 14 prestigious Marcus Wallenberg Prizes given for pathbreaking achievements in science and technology related to the forest industry. A recent international review of scientific capacity conducted by the chief science advisor in the UK noted "… Canada … [has] prominence in research based on natural resources" (May, 1997). This study also found that the cost-effectiveness of Canadian science was the highest of the 15 countries ranked (including the entire G7).

Companies manufacturing and marketing commodity products involving little or no proprietary technology can exist with relatively little intramural R&D. Instead, they depend heavily on generally available technological advances provided by suppliers. The competitive edge (if any) for companies using this strategy depends on their ability to be low-cost producers and to invest in new capital facilities more skillfully than their competitors. This strategy, nevertheless, requires excellent levels of technical knowledge and operating competence resident at the manufacturing facilities (Binkley, 1995). While the assessment of operating competence falls outside the main scope of this report, we do make some comments on the current situation.

Data Collection Methods

The data below reflect both secondary data (especially those collected by Statistics Canada) and primary data assembled from individual firms, research institutes, and government agencies. Colleagues in the Canadian Forest Service assembled the data for that agency, as did personnel from the Natural Science and Engineering Research Council (NSERC) for their programs. Consistent data from other agencies in the federal government (e.g. the IRAP program of Industry Canada) were unavailable. The totals do not include the so-called "tax expenditures" associated with federal or provincial income tax deductions available to profitable firms making qualifying expenditures. Information on provincial government expenditures was collected from four bellwether provinces (British Columbia, Alberta, Ontario and Quebec) who provide the bulk of the non-federal public funds for forest sector R&D. R&D expenditures from Alberta's FRP program are apparently not included in the provincial totals, but are presumably reflected in the industrial expenditures in that province.

We sought annual data for the period 1982 to 1997, but focused particularly on the four quinquennial years covering this period. When stated in real terms, the data were deflated by the Statistics Canada GDP deflator and stated in $1986.

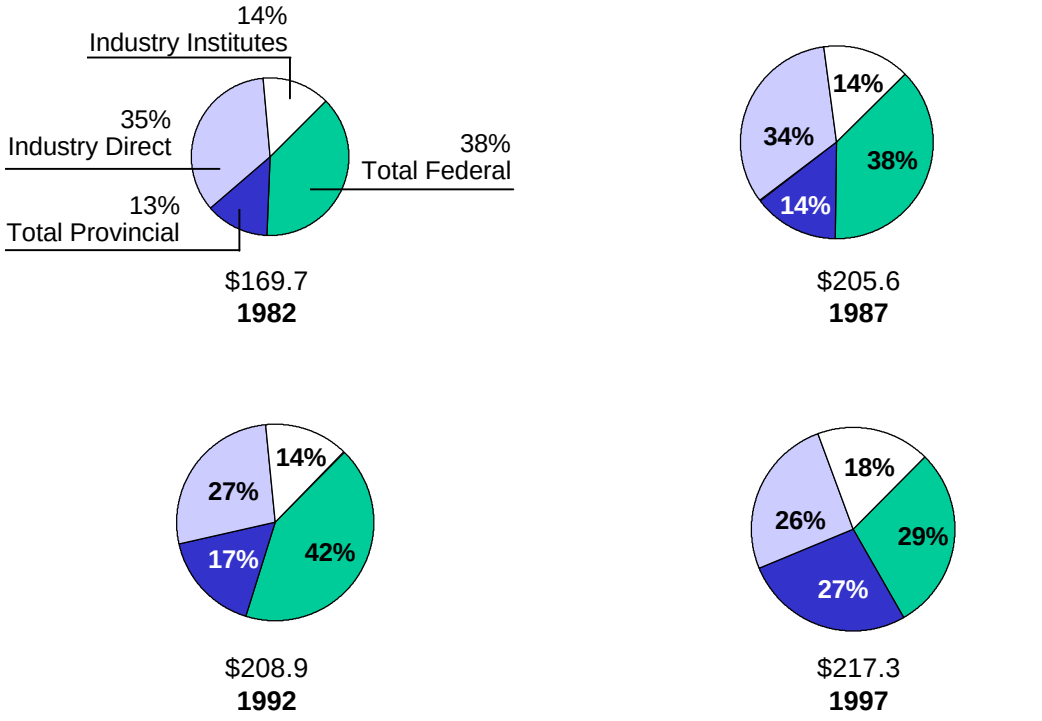
Our data collection efforts were focused on identifying the *sources* of funding, and a great deal of care was expended on eliminating double counting. For example, the collaborative industry research institutes (the Pulp and Paper Research Institute of Canada — Paprican, the Forest Engineering Research Institute of Canada — FERIC, and Forintek Canada) all derive part of their funds from the federal government, although the fraction differs significantly among the institutes and over the years. We attribute the government portion of the support for these institutes to the government, and the industry portion (dues and contracts) to the industry. As another example, the NSERC collaborative R&D programs and National Centres of Excellence (NCE) rely on federal, provincial and industry support. Only the NSERC component would be attributed to the federal government. Undoubtedly our attempts to disentangle such complex funding arrangements were imperfect, but our intentions were clear.

The data below do not break out universities separately. In part this occurs as a result of our focus on *sources* of funding. Most of the funds universities expend on R&D come from either the federal government, the provincial research organizations, or industry (either directly or as part of collaborative grant schemes). The only unique funds would be some amount of faculty salaries that could be attributed to R&D, and funds obtained from sources other than those included in the survey (e.g. private foundations, regional authorities, international agencies). A recent study of the forest sector R&D in B.C. (Binkley and Watts, 1992) found that universities provide directly only 3% of the total R&D expenditures in the province. The budgets of the eight Canadian university-based forestry faculties equalled about $22 million in 1991. If one third of this total can be attributed to R&D activities, this would equal about 3% of the total Canadian R&D expenditures. Beyond the forestry schools, it is extremely difficult to identify the universe of possible university researchers who might be involved in

forest sector R&D, and initial attempts to solicit information from those who were identified were largely unsuccessful.

3. Trends in Forest Sector R&D Expenditure

Figure 1 shows the evolution of forest sector R&D funding from all sources in Canada during the decade and a half between 1982 and 1997 (Appendix Table 1 includes the details). After an initial increase between 1982 and 1987, real expenditures have risen only slowly (0.6%/yr). In 1994, expenditures equalled about 0.4% of the value of shipments, down from about 0.6% in 1982. This contrasts with 1.5% in the United States and 1.75% in Sweden for recent years (Binkley and Watts, 1992).



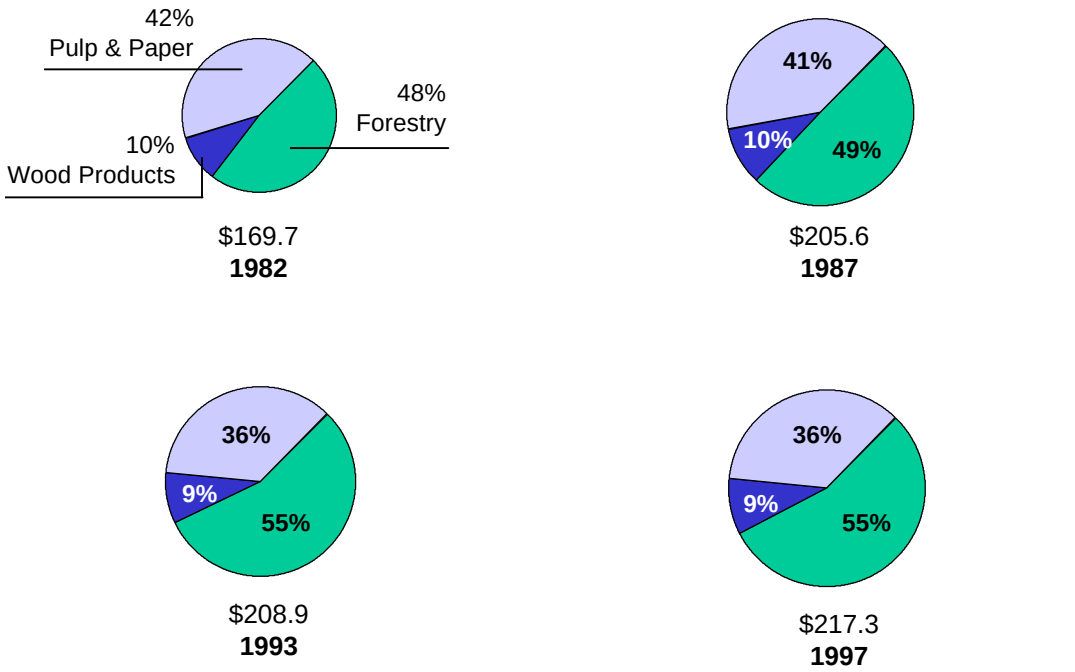
Sources: Statistics Canada; CFS; current study (see Appendix)

Figure 1. Trends in R&D expenditures by source, 1982 – 1997
(total expenditure in $1986 millions, given below pie chart)

While the total expenditures have not changed a great deal during the past decade, the distribution among funding sources has. Federal expenditures have declined by $14.4 million (18.4%), with much larger reductions in the Canadian Forest Service's programs being partially offset by a $4.4 million increase in NSERC's. Aggregate provincial contributions to forest sector R&D have actually increased, because the $31.5 million increase in B.C. (associated with the new Crown corporation Forest Renewal BC) has offset declines elsewhere. Industrial expenditures have declined slightly (0.3%/yr), with reductions in direct expenditures offsetting increases in the collaborative research institutes.

Figure 2 shows the trends in expenditures among the three sub-sectors, forestry, wood products and pulp and paper (Appendix Table 2 provides the details). Over the 1987-1997 period where expenditures have been roughly constant, the share of R&D devoted to forestry has increased from 49.4% to 54.6%, while the shares for wood products and pulp and paper have declined. The decline in the later case has been most marked, from 40.6% of the total to 36.0%.

It is useful to examine these trends in greater detail.



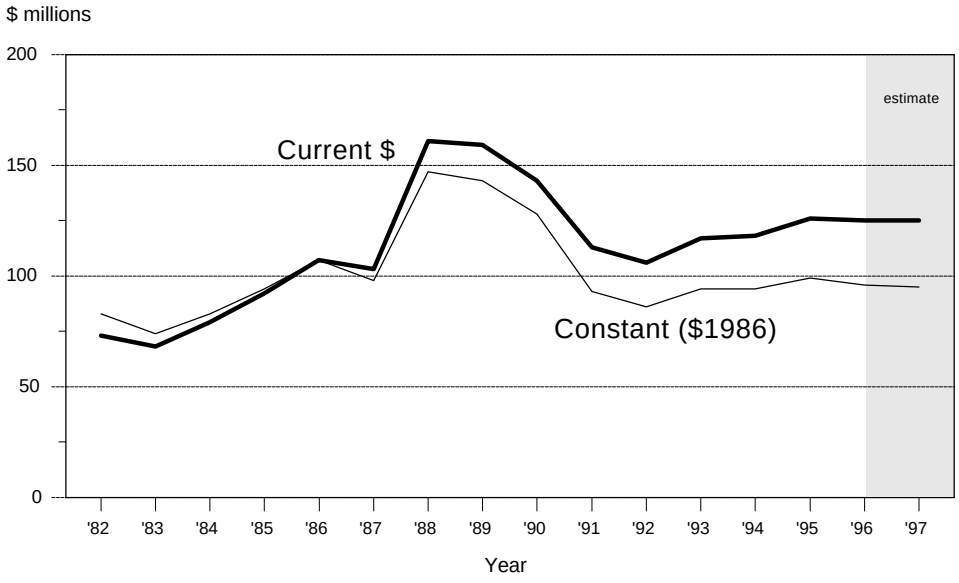
Sources: Statistics Canada; CFS; current study (see Appendix)

Figure 2. Trends in R&D expenditures by sector, 1982 – 1997
(total expenditure in $1986 millions, given below pie chart)

Industrial Expenditures on R&D

Figure 3 shows the total (operating and capital) intramural spending on R&D by the industry from 1982 to the present, in current and in constant 1986 dollars, including the industry contributions to the costs of operating the three collaborative research institutes.

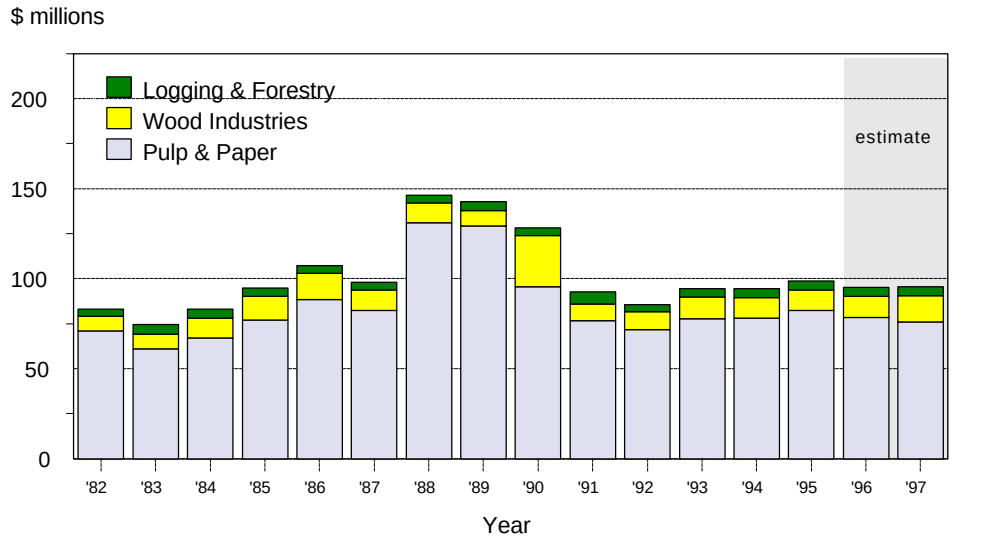
The data show a major upwards bulge in the period 1988-1990. Our investigation found this increase to be clearly attributable to the unique coincidence of several major capital expenditures for prototype-plants, especially those related to the ALCELL project in New Brunswick, investment in a new research centre by MacMillan Bloedel in Burnaby, B.C. and new laboratory facilities constructed by Domtar at Senneville, Quebec. (Statistics Canada data indicate that, in the absence of extraordinary capital items, capital expenditures to support R&D in the industry generally equal 10% to 15% of operating costs.) Since 1990, however, total expenditures have remained essentially level, and are more representative of the current situation.



Sources: Statistics Canada; CFS; current study

Figure 3. Total intramural spending on R&D by the Canadian forest products industry, 1982–1997 (Paprican, Forintek and FERIC included)

Figure 4 shows the industry intramural R&D data broken down into forestry (mainly wood harvesting), wood products and pulp and paper. Pulp and paper projects account for more than 70% of the spending. Of the remainder, less than 20% represents R&D dedicated to the wood products sector, and less than 10% was dedicated to logging, log transportation and silviculture. This comparatively low level of industrial expenditure on forestry-related R&D is not too surprising — licensees have



Sources: Statistics Canada; CFS; current study

Figure 4. Industry intramural R&D expenditures by sector, $1986 (Paprican, Forintek and FERIC included)

only weak property rights to forest land in much of Canada, and, as a consequence, investments in forest-related R&D have highly uncertain payoffs to the firms involved. Issues such as sustainability that arise in some international markets are being handled through far more rigorous forest practice audits than exist anywhere else in the world. As a result, there has evidently not been a perceived need for more R&D in this area.

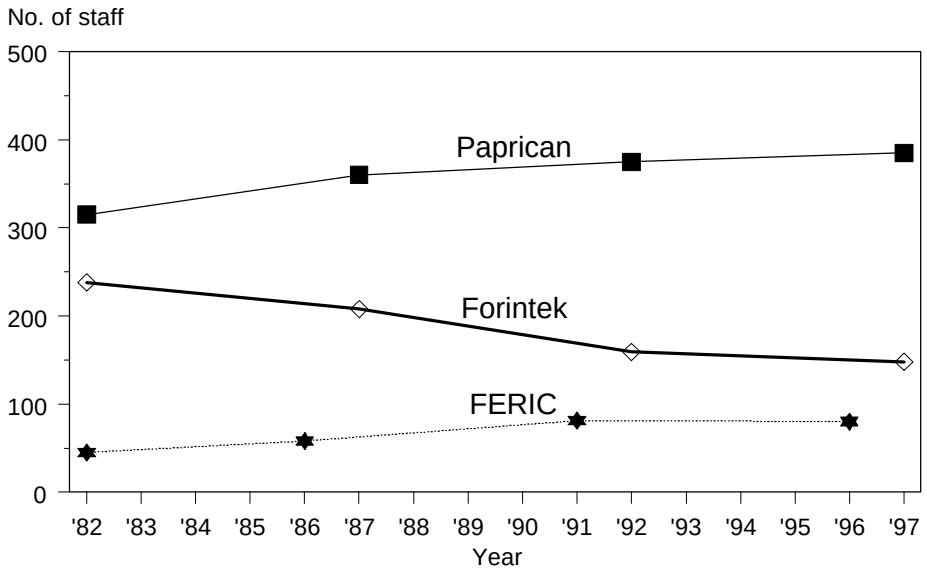
Data on total expenditures do not tell the whole story. The number of people employed in R&D is another, perhaps a more robust indicator of trends. Figure 5, based on statistics collected by IRAP on behalf of the Research Committee of the Technical Section, Canadian Pulp and Paper Association, shows a decline in the number of R&D performing employees within most of the major pulp and paper companies throughout the period (similar data are not available for forestry or wood products industry R&D, but, based on expenditures, the total would surely number fewer than 100 at present, and would be declining as well).

Sources: Tech. Section CPPA; IRAP

Figure 5. Total number of employees performing R&D within 13 reporting pulp and paper companies

Further evidence of this decline is provided by the number of companies claiming discounts against their Paprican assessments that are available for intramural pulp and paper research: in 1986, *eleven* companies claimed this discount, but by 1996, the number had dropped to *eight*, including two companies that were not on the 1986 list. It is tempting to conclude that five major companies out of eleven were no longer spending enough on intramural research and development to justify the paper-work to claim an assessment reduction.

The decrease in the number of R&D workers in the companies is partly offset by an increase in the number of people working at FERIC and Paprican, although staff numbers at Forintek have declined (Figure 6).



Source: Current study

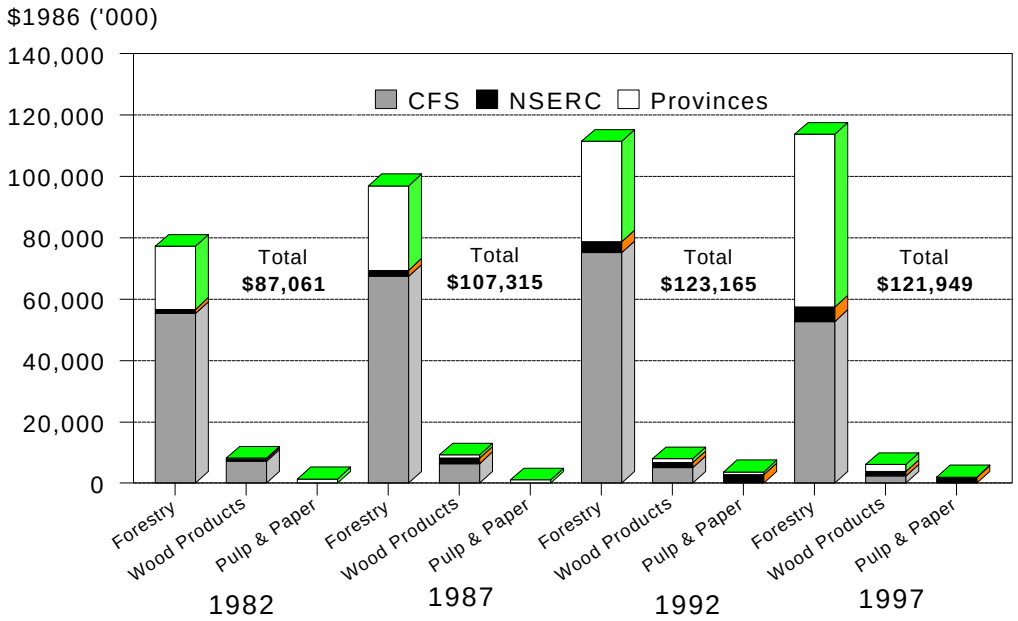
Figure 6. Staffing trends in the three collaborative industry research institutes

Public Expenditures on R&D

In Canada, justification for public expenditures on forest sector R&D rests on two main grounds. First, as the owner of most of the forest land in the country, governments have a general societal responsibility for forest stewardship, and forest-related R&D is part of this general responsibility. In part this responsibility is provincial, since the Canadian constitution locates control over forests with the provinces. In part the responsibility is federal as a result of trans-provincial issues such as forest health and international issues such as market access and treaty agreements. Second, forests and forest sector R&D have many public good aspects. Examples range from the prosaic — investments in training by one firm accrue to another if the employee leaves — to the global — the carbon fixed in forests benefits all humans by helping to offset emissions from fossil-fuel consumption. As these public good aspects of the forest sector become more important, one would expect the governmental responsibility in forest sector R&D to increase. Even the most conservative theories of government support public intervention in these cases, and other theories of government would build upon these.

While these theories suggest a government responsibility in forest sector R&D, they do not necessarily suggest a direct government role. R&D activities associated with forest stewardship could be contracted out to licensees, much as forest management responsibilities are currently. R&D activities associated with public goods can be handled in numerous, well-known ways. So, the adequacy of direct public expenditures in forest sector R&D must be considered in light of both the special role for government in this area and the level of private-sector R&D activities. We have seen that the former is small — particularly in the forestry area where the public role is the greatest. What about public expenditures?

Figure 7 shows public-sector expenditures on R&D broken out by industry subsector. First note that the federal expenditure in the pulp and paper sector is quite small, but may be understated in our data which excludes IRAP expenditures. Second, the decline in Canadian Forest Service support of wood products research has been partially offset by increases at NSERC and from the provinces. Third, the great bulk of public R&D expenditures are on forestry, as one might expect for the reasons



Source: Current study

Figure 7. Public expenditures on forest sector R&D

outlined above. Despite the increase in NSERC funding, total federal support has declined signifi-cantly over the period. This decline is inconsistent with the rapidly increased demand for knowledge-related activities in the federal sphere — international environmental agreements (global change, biological diversity), non-tariff barriers to trade (pinewood nematode, national building codes in trading-partner countries). The increased provincial funding for forestry R&D can be entirely accounted for by the research program of the new crown corporation Forest Renewal BC, a program that deals only with problems relevant to that one province. One would expect that these shifts in funding sources would probably signal shifts in programs funded, however we have no data to confirm this directly.

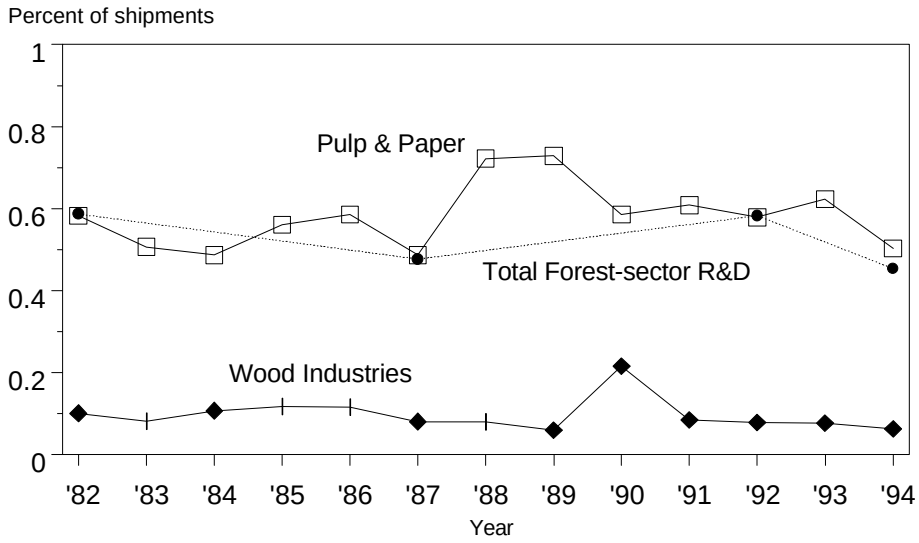
4. The Strategic Dimensions of R&D

Data on levels and trends in forest sector R&D are, by themselves, of comparatively little interest — declines in expenditures could indicate an appropriate response to an eased competitive position, and increases could indicate an inappropriate high level of investment. To put the survey figures into context, it is necessary to answer the question "Is the apparent trend in R&D spending appropriate in view of the challenges facing the Canadian industry?" We believe that two parameters are useful in addressing this question. The first is *R&D intensity*, and the second is *the absolute size of the corporate R&D organizations*, (especially whether or not they are of the critical size usually required to undertake projects more complex than technical service work or minor incremental changes in technology).

R&D Intensity

R&D intensity can be measured by R&D expenditures expressed as a percentage of shipments or sales. This measure can be misleading when comparing individual companies (e.g. a company's sales may include the resale or distribution of products manufactured by others — for example, in 1996 36% of MacMillan Bloedel's sales were produced by other manufacturers), but it is useful in comparing the

requirements of different groups of products, and examining the impact of changes within a product group towards added value. Figure 8 shows that the research intensity for the Canadian forest sector varies between 0.5% and 0.7% (excluding extraordinary capital expenditures) for pulp and paper, and between 0.06% and 0.2% for the wood industries. The research intensity of the wood products industry has actually *declined* by almost half over the past 15 years, despite the enormous business opportunities in engineered wood products, societal demands for higher valued-added products, and the competitive threats from rising costs and alternative materials. Omitting the capital expenditures reduces the aggregate R&D intensity of the Canadian pulp and paper sector to roughly between 0.4 and 0.55%.



Sources: Statistics Canada; CFS; current study

Figure 8. Research intensities of the wood and pulp & paper industries sectors

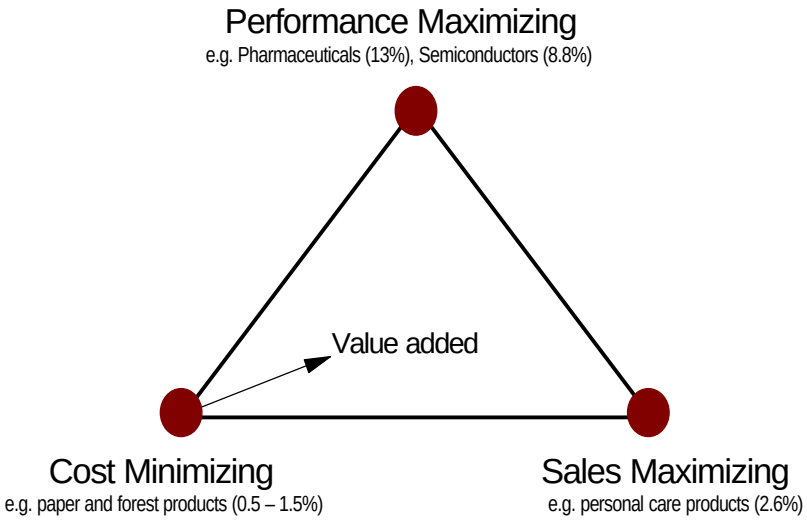
To examine the level of R&D that is appropriate for a particular industry sector, it is useful to consider the alternative modes of competition. One simple but lucid classification system was first proposed by Ayres (1969) and later expanded by Simmonds (1973). Ayres and Simmonds point out that all manufacturing industries compete in three ways, which can be described as *cost minimizing*, *performance maximizing* or *sales maximizing*.

- **Cost minimizing** industries produce commodities, such as dimension lumber, newsprint, steel and petroleum, where the product prices are determined by world markets. The products from different suppliers are largely undifferentiated and tend to change very slowly with time. Delivered costs to a particular market determine relative performance of different producers. Raw material and energy costs, and the efficient use of capital equipment are among the key financial drivers. Access to raw materials usually determines the location of manufacturing facilities. Internal R&D needs as a percentage of sales are relatively low, and are focused on productivity, cost reduction, quality control and the minimizing environmental impacts. These requirements are often generic, and therefore lend themselves to shared research through jointly funded research organizations. Suppliers are largely responsible for providing new technology, and their interests lie in the broad diffusion of the innovation rather than in creating competitive advantage for an individual firm. As a net exporter in a high-wage country, reliance on ubiquitous technology is a risky strategy for Canada (Binkley, 1995).

- **Performance maximizing** industries compete principally on the basis of knowledge. Software, scientific instruments and proprietary pharmaceuticals are typical examples. Products are highly proprietary and command prices based on performance. Product obsolescence is rapid, and survival depends on a constant flow of new knowledge-based-products. Location depends on access to people, but with today's electronic communications, firm location is becoming less and less important. Such companies can easily relocate. R&D is the lifeblood of such industries and is large in proportion to sales. It is usually intramural, and the results are carefully guarded by secrecy, patents and trade marks.

- **Sales Maximizing** industries are driven by promotion, advertising and distribution. Typical examples are consumer products, such as tissue products, soaps and cosmetics. Margins tend to be low, and market share and volume determine profitability. Research is driven principally by the need to maintain consumer interest and confidence, and is highly related to trends in consumer preference.

These three modes of competition can be represented as the corners of a triangle, as shown in Figure 9. Any move away from the production of undifferentiated commodities usually requires an increase in R&D. Economists define "value added" as the difference between product values and production costs (excluding labour). While any of the three strategies can, in principle, add value, the efficacy of one over the other depends critically on the particular circumstances. With rising input costs (especially for wood), and a desire to sustain high wages, cost minimizing alone no longer seems to be a tenable strategy for the Canadian forest sector. Transformation of the sector into higher value added will inevitably require higher expenditures on R&D than occur at present.



Source: Data from Business Week, June 27, 1995

Figure 9. R&D spending as a percent of sales
Each corner of the triangle indicates one of the three modes of competition. A move out of the commodity corner, especially in the direction of performance maximizing implies an increase in R&D intensity to stay competitive.

Lindström, Research Director of Mo Och Domjo AB of Sweden recently presented a table of R&D intensities in the pulp and paper industry. Table 1 includes his presentation, and adds the right-hand column to illustrate his conclusions with actual published data. The relationship between R&D spending

and mode of competition is clearly apparent in this analysis. The Canadian industry, and the forest sector as a whole in Canada, fall in the range characterized by "lower value-added commodities" and "cash-cow philosophy", a term that refers the strategy of extracting cash from a declining industry through a policy of depreciation of capital assets without commensurate reinvestment. Such a strategy can be pursued by individual firms wishing to reinvest in other sectors, or by governments through higher timber, power or tax costs that disable the levels of investment needed to sustain the industry's competitive position.

How does the Canadian forest sector's R&D performance fit with this strategic model? The *increase* in the budget and staffing of FERIC and PAPRICAN over the last 15 years seems justified, if only to understand and control the environmental impacts of wood harvesting and the manufacture of pulp and paper products. These issues are fundamentally generic to the industry. For similar reasons, the overall decline in funding for forestry R&D (with Forest Renewal BC being the only bright light in an otherwise dim scene) is not consistent with the collective problems related to the environment and trade facing the sector as a whole.

The decline of corporate R&D seems inconsistent with the achievement of the industry's frequently stated objective, that is, to remain competitive in the face of rising costs and strengthening global competition by adding more value to their products.

Table 1. Typical R&D investments (% of revenues) in world pulp and paper industries

Specialties	Typical range	Examples	
Consumer products or high value added products	> 1.5	Kimberly-Clark (US) SCA (Sweden)	2.3 1.4
Commodities			
High end Growth- and quality-oriented pulp and paper products companies	0.7 – 0.9	Westvaco (US) Metsä-Serla (Finland) STORA (Sweden)	1.1 1 0.8
Medium Lower value-added commodities	0.3 – 0.4	Weyerhaeuser (US)	0.5
Low "Cash-cow philosophy"	< 0.3	Most Canadian companies	
World average	0.5		

Source: Lindström, 1996; Business Week, July 1995

It seems unlikely that this challenge to the future profitability of the traditional lumber industry can be met without the development of new products and markets which are capable of commanding higher margins. It is unlikely, in turn, that the development of such new products will be achievable by an industry that spends less than 0.2% of sales on R&D. The decline in the real budget for Forintek in the past decade provides no contrary evidence. To date, only one major Canadian based forest products company has made a substantial and sustained R&D investment in this area. We believe that new

product development in wood-based building materials holds considerable promise for industrial growth in Canada (Forgacs, 1995). Alternatively, unless such technical development occurs Canada will face daunting challenges as plantation timber and engineered wood products supplant our traditional products (e.g. pruned radiata pine from New Zealand and Chile substituting for old-growth timber; MDF moldings substituting for clearwood; wooden I-beams or LVL manufactured from plantation-grown eucalyptus substituting for softwood 2x10s).

However, there are some positive signs. For example, faced with the declining North American demand for newsprint, the Canadian newsprint industry has been inching its way up-market towards higher valued-added products. Standard newsprint production, once the dominant product, now represents only 30% of Canadian industry capacity, down from 41% in 1986 and is expected to decline further. We question, however, if the R&D activity of the Canadian industry is great enough to offset the large adverse cost pressures it faces. To the extent that this shift has been accomplished largely with readily available technology and know-how, the overall effect may only have been to convert what was once a specialty product into a commodity.

Scale of R&D Activity

While overall levels of forest sector R&D activity are low when compared internationally, and R&D activity in the wood products sector is minuscule, at first sight it appears that the aggregate R&D spending of the Canadian pulp and paper industry at about 0.5% of sales is not far out of line with its international commodity manufacturing competitors.[3] However, R&D intensities ignore the effects of *scale* of R&D activity. Virtually every US, Swedish and Finnish company is larger than its largest Canadian competitor. The relatively modest R&D to sales ratios understate the presence of substantial corporate R&D organizations, as indicated in Table 2.

Even at an intensity of only 0.5% or 0.6% of sales, these large companies are capable of support-ing significant R&D portfolios. Note that in 1994, International Paper spent more on R&D than all the Canadian pulp and paper companies combined, while SCA spent over 80% of this total. Based on experience, any pulp and paper company with fewer than 30 employees assigned to R&D is unlikely to use these people for anything other than technical service to the mills.

Despite the relatively large size of the Canadian forest products industry as a whole, not one Canadian company is represented among the 40 largest companies in the industry world-wide in 1995 (Pulp and Paper International, 1997). For that year, based on shipment data for pulp, paper and paper converting companies, Avenor heads the Canadian list at 41, MacMillan Bloedel ranks 46 and Domtar ranks 47. Despite frequent reference by the Canadian media to these Canadian companies as “giants”, they are in fact all *undersized* in their ability to undertake large capital projects without major risk to

[3]The US aggregate in 1994 was 1%, but when consumer products companies such as Kimberly-Clark and Scott Paper are omitted, the ratio drops closer to 0.7%. International paper spent 0.7% of sales, and Weyerhaeuser 0.5% (Business Week, July, 1995. Until 1995, Business Week published an annual scoreboard of R&D spending in US industry. Unfortunately, this survey has been discontinued). In Sweden, SCA with over 42% of sales in consumer products spent 1.4% of sales on R&D, but the rest of the industry was closer to 0.7%. In Finland, the average also was around 0.6%, with the exception of Metsä-Serla (1%), which makes relatively specialized products.

Table 2. Total R&D expenditures, 1994 data

	$US (millions)	% of sales
Sweden		
Assidoman	15.6	0.6
SCA	69.7	1.4
MODO	22.2	0.8
STORA	53.0	0.8
Finland		
Enzo	26.5	0.8
Metsä Serla	18.2	1.0
UPM[1]	22.1	0.6
Kymmene	18.2	0.5
Arjo-Wiggins	21.5	0.5
U.S.		
Weyerhaeuser	47.0	0.5
International Paper	102.3	0.7
Canada		
Industry and their funding of the three main institutes	86.6[2]	0.20
Total including government funding	153.8[2]	0.36

Source: Lindström, 1996; Business Week, June 27, 1995

[1]Now merged with Kymmene.
[2]Converted to US$ at 1.38.

the enterprise, to hold their own in price negotiations with today's huge printers and packaging customers, and apparently to achieve critical size in their research and development organizations.[4]

Why is scale important to the R&D enterprise? Companies capture the benefits of R&D through capital investments. The economics of the forest sector dictate that firms generally operate several similar manufacturing facilities at different locations. Capital investment often involves installing the same equipment at each of these facilities. Larger firms can amortize the relatively fixed costs of innovation across a larger number of operating units, thereby reducing the unit costs of bringing a new technology on line. Unless Canadian firms grow is size within product lines, it is unlikely that they will ever be able to deploy technology as an winning competitive strategy. Since technology is the only means available for dealing with the upward cost pressures in the sector and the competitive

[4]This disadvantage is well recognized within the Canadian industry and by some provincial governments. For example, Quebec encourages mergers, even if it entails a net loss in jobs: Donohue recently doubled in size by acquiring Quno and other assets; Abitibi agreed to merge with Stone Consolidated to form a $5 billion company; Alliance at least doubled with the acquisition of Coosa Pines. It is likely that further mergers and acquisitions will take place this year. Other provincial governments, notably B.C.'s, have not only failed to encourage this trend, but have actively resisted it. For example, it blocked the acquisition of Slocan by Canfor. Attempts to sell the B.C. assets of Repap have not, to date of writing, attracted a single serious offer.

challenges from new regions and other industries, the failure of some Canadian governments to permit Canadian firms to grow will reap bitter rewards for all who depend on the forest sector, directly or indirectly.

Although collaborative efforts would seem to offer similar benefits, the technology developed by such consortia is no longer company-specific. As a consequence, it can generate little if any competi-tive advantage to any one firm. When relying on collaborative technological efforts, the technology policy becomes, at best, one of trailing the industry's technological leaders. Added to these inherent liabilities of collaborative R&D are the complications of negotiating a R&D program acceptable to all participants. An all-to-frequent result is a minimal program that is no more than that which is acceptable to the least-technically adept firm. While collaborative R&D initiatives have been and can be successful for dealing with generic issues facing the Canadian forest sector (e.g. control of environ-mental impacts of manufacturing processes, access for Canadian species and products to international markets, the science underlying international environmental agreements), it is doubtful that they alone can be successful in creating lasting competitive advantage for Canadian firms.

4. Conclusions

The forest sector comprises a large share of the Canadian economy (especially in non-metropolitan areas) and has generated considerable wealth for Canadians during the past century. The success of the industry has been based on rising regional and global demand for its products and the lack of available substitutes for wood logged from primary forests. While the underlying factors which drive global wood products demand — growth in population and in income — are expected to remain strong for the foreseeable future, the Canadian forest sector faces daunting competitive challenges in the other areas of its traditional strength. At present, plantation-grown wood competes directly for many of our pulp and paper products and some solid-wood products. High lumber prices have helped offset increased costs, but have also triggered substitution of other materials — steel, concrete and plastics — for wood products. Revenue-pinched governments have raised stumpage fees, increased environ-mental concerns have engendered higher regulatory costs, and the endogenous dynamics of the sector have pushed logging into increasingly remote and costly areas.

Aside from unilateral reductions in those cost factors under direct control of government, innovative technology is literally the *only* strategy available for companies to meet these competitive challenges while sustaining the high wage rates that have desirably characterized the Canadian forest sector. Innovative technology requires R&D to generate the innovations, a highly skilled workforce to adopt and manage the innovations, and a business climate that encourages the capital investments needed to put these innovations in place. This paper deals primarily with the first factor, with full recognition that all three are essential components.

Given the importance of R&D for industry competitiveness, we are surprised at the poor quality of the available data. The management axiom "if you don't measure it you can't manage it" is apt. At present, we do not have a mechanism for monitoring the technological strength of the industry, or to benchmark it against foreign competition. Data on R&D are difficult to collect and to interpret. It is easier to monitor the number of technical and scientific people in the industry than to monitor R&D spending *per se*, but there is no data base for this key indicator. Were the country truly serious about the need for increasing value-added in the forest sector, one would expect far greater attention to understanding and managing the process of technical innovation.

When viewed in the context of a simple model of business strategy, Canadian investments in forest sector R&D are, at best, marginal. While the pulp and paper sector comes up to the low end of the range

for international competitors, this level of expenditure does not appear to be adequate to meet the increasing competitive challenges faced by Canadian firms. A substantial part of the Canadian forest industry's paper production has been shifting gradually from standard newsprint to higher value grades of groundwood printing papers, the shift to these technically more demanding products has is not reflected generally in the level of R&D expenditures. Canadian firms tend to be considerably smaller than their international counterparts, so R&D intensities as conventionally measured tend to *overstate* the technical capacity of the Canadian forest sector in international comparisons.

R&D performance in the solid-wood products sector appears to be far below the levels needed for effective industry transformation. This industry comprises about 40% of the forest sector Canada-wide. It faces major challenges associated with high and rising wood costs, and fierce competition from new timber supply regions, new engineered wood products and alternative materials. For example, in the last decade, wooden I-beams have taken perhaps one quarter of the floor-joist market in North America, supplanting 2x10's that have been a mainstay of the Canadian lumber business. This substitute product can be manufactured from low quality wood, thereby eroding a traditional Canadian competitive advantage.

While it is more difficult to place the data for forestry R&D in a similar international comparison, the singular lack of industrial participation (a predictable consequence of typical Canadian patterns of forest tenure) and the overall downward trends are troubling. The major new forest sector R&D program supported by Forest Renewal BC is the only positive trend in an otherwise bleak outlook although the effectiveness of their research management approach remains to be seen. It is difficult to imagine that the increasingly complex public challenges surrounding the practice of forestry, both locally and internationally, can be successfully met with declining technical resources. And, there is also the need to sustain and increase the industrial productivity of Canada's forests as the foundation for a successful forest sector in the future. While our competitors in such countries as Brazil and New Zealand devote substantial attention to the comparatively narrow technical problems of timber production, Canada's very limited R&D resources diffuse across a far broader array of issues.

R&D is nothing more or less than an investment in the future — of a firm or of a country. As such, it is logical to consider the performance of R&D in the context of returns on investment. As we have pointed out, the returns to R&D investments are heavily conditioned on the scale of firm. Canadian firms are small by international comparisons. Without a change in the structure of the Canadian forest products industry, it is unlikely that its R&D activity will ever reach a scale large enough to achieve the needed transformations. It remains to be seen whether the current wave of mergers will actually move these companies towards more technology-intensive strategies.

Similarly, the capacity of Canadian firms to exploit the results of R&D appears to lag that of our major competitors. For example, a 1988 comparison of the technical personnel situation in Canadian mills and their Scandinavian and German counterparts found that, while some of the Canadian industry's pulp and paper operations were equal to the best elsewhere, the average performance in terms of operating efficiency, including the application of state-of-the-art control systems and preventative maintenance techniques lagged behind the Swedish and Finnish mills (Omni Continental, 1988). This in turn could be related to both the quality of technical management and operator training and education, which were substantially more advanced outside of Canada. A new emphasis on wood products processing education, for example, at the University of British Columbia should eventually help to alleviate the shortage of trained managers and engineers at the sawmills and other wood processing plants.

As a result of the forest tenure patterns typical in Canada, the returns to private R&D investments in forestry are highly uncertain regardless of their underlying technical merits. A large fraction of the forestland is owned by the government and leased to companies through legal arrangements that convey only weak and unreliable property rights. Hence, licensees are not necessarily guaranteed the results to any land-based investments they make. Stumpage systems in Canada typically assume that, colloquially, "all profits flow back to the stump". Such policies disable the potential returns from investments in improved processing capacity, and compound the problems created by weak property rights. Privatization of forest land rectifies these problems, but is not the only solution (c.f. New Zealand's sale of long-term leases, with ground rent collected rather than stumpage). In the absence of such structural solutions, the burden for forestry R&D falls squarely with the public sector. Squeezed between shrinking budgets and rising concerns with nontimber aspects of the forests, R&D devoted to timber production undoubtedly suffers. Yet each year Canada's competitors improve the productivity of their forest lands through wise investments in such fields as genetic modification, soil-site relationships and the silvicultural effects on wood properties.

Beyond government's obvious responsibility for research related to the publicly-owned land base, there are other legitimate areas for its involvement in forest sector R&D. As a general matter, government intervention is justified when the benefits of an investment accrue more broadly than to one firm alone. Such "spillovers" can occur in many ways. Education and training for technical personnel are obvious examples. University R&D infrastructure is another. Much pre-commercial R&D might fall into this category as well. Similarly, the R&D needed as the basis of regulations or international agreements provide benefits to the sector broadly.

While it is clear that the government has a central role in ensuring that an appropriate level of such R&D takes place, a public interest in such activities does not necessarily imply a direct public responsibility to undertake specific R&D activities. For example, government might levy an R&D tax (at, perhaps 1-2% of sales, as a substitute for other currently applied taxes). Firms could have the option of either paying the tax (to fund sector-specific research) or spending the money themselves on their own R&D priorities. Such "play or pay" schemes exercise the public sector's legitimate responsibility to overcome the kinds of externalities described above without necessarily removing the direction of R&D from those closest to the problems.

An increase in the overall level of technology—from innovative R&D to the ability to transfer technology and operate at the leading edge—is one of the few controllable means at the disposal of the Canadian industry to improve its long-term performance. While improving the public programs related to forest sector R&D (tax deductions, special levies, and direct performance by public-sector agencies) are of course helpful treatment of R&D, they treat the symptoms of a problem rather than the cause. Reversal of the current trend of low and declining expenditures on R&D will take time to deliver results. In the short term, every effort is needed by the federal and provincial governments to help restore the industry to earning a more acceptable return on capital, so that he needed investments in technology can be made. Governments which support mergers within the forest sector help achieve economies of scale when measured against international competitors. Governments must also avoid the temptation to view the industry — because of its large fixed capital and the relative immobility of the forests themselves — as an easy target for extracting higher levels of direct government revenues, whether through higher stumpage fees, power costs or taxes. The alternative is a downward spiral of reduced technical innovation and capital investment producing weakened competitive positions leading to less capacity to make the needed investments. This would seem unwise public policy for an industry that simultaneously contributes greatly to domestic prosperity and is a major market for many of Canada's emerging high technology firms.

Acknowledgement

The authors gratefully acknowledge the valuable assistance provided by Susan Watts, University of British Columbia, Faculty of Forestry. Mary Mes-Hartree and René Samson, Canadian Forest Service, Ottawa, assisted with the difficult task of assembling the data for this paper. For this we are greatly appreciative. The Canadian Forest Service provided the financial support that made this paper possible. This paper was originally delivered at the National Forest S&T Forum, Toronto, 2-3 June 1997.

Literature Cited

Ayres, R.U. 1969. Technological forecasting and long-range planning. (McGraw Hill, NY)

Binkley, C.S. 1997. Ecosystem management and plantation forestry: the case for allocation with illustrations from British Columbia. **For. Chron.** (forthcoming).

Binkley, C.S. 1997. Designing an effective forest sector research strategy for Canada. **For. Chron.** 71:589-595.

Binkley, C.S. and S.B. Watts. 1992. The status of forestry research in British Columbia. **For. Chron.** 68:730-735.

Booth, D.L., D.W.K. Boulter, D.J. Neave, A.A. Rotherham, and. D.A. Welch. 1993. Natural forest landscape management: A strategy for Canada. **For. Chron.** 69:141-145.

Forgacs, O.L. 1995. Engineered wood products. Workshop on new products and equipment for the forest industry. Quebec City, March 30-31, 1995. Workshop Proceedings No. 4, Industry Canada.

Lindström, T. 1996. R&D in the European pulp and paper industry. Paper presented at the Annual European Meeting of the Empire State Paper Research Association. Maastricht, May, 1996.

MacCallum, M. 1997. The forest industry in British Columbia. 1996. Price Waterhouse 10th Annual B.C. Forest Industry Conference, March 4, 1997. Vancouver.

Marchak, P. 1996. Logging the globe (McGill-Queens University Press: Montreal)

May, Robert M. 1997. The scientific wealth of nations. **Science** 275(5301):793-796.

McCaig, G. and E. Harala. 1997. Manufacture of No.5 light-weight coated using on-line Film Press Coating. Paper presented at the CPPA Annual Meeting, Montreal, Jan. 1997.

Omni Continental Ltd. 1988. Comparison study of technology in the Canadian forest products industry compared with the European industry. Commissioned by the Technical Section, Canadian Pulp and Paper Association (1988) and quoted by permission of the Technical Section.

Pulp and Paper International. 1997. Annual survey of the world's Top 150 pulp and paper companies. September, p 33-39.

Simmonds, W.H.C. 1973. Toward an analytical industry classification. **Tech. Forecasting and Soc. Change** 4:375-385.

Solberg, B. (ed.) 1996. Long-term trends and prospected in world supply and demand for wood, and implications for sustainable forest management. European Forest Institute Research Report 6 (Joensuu, Finland).

Appendix – Table 1. R & D Expenditures by Funding Organization ($1986 millions)

	1982		1987		1992		1997		% change
	$	%	$	%	$	%	$	%	1982-1997
GOVERNMENT									
Federal									
CFS	62.6	36.9%	73.8	35.9%	80.2	38.4%	55.1	25.3%	-12.0%
NSERC	2.0	1.2%	3.8	1.9%	7.9	3.8%	8.2	3.8%	300.8%
Total Federal	$64.6	38.1%	$77.6	37.8%	$88.1	42.2%	$63.3	29.1%	-2.0%
Provincial									
B.C.	10.6	6.3%	13.7	6.6%	18.6	8.9%	45.2	20.8%	326.4%
Alberta	1.5	0.9%	1.3	0.6%	1.0	0.5%	0.4	0.2%	-72.7%
Ontario	4.6	2.7%	3.0	1.5%	3.3	1.6%	3.4	1.6%	-25.9%
Quebec	5.5	3.3%	11.8	5.7%	12.3	5.9%	9.6	4.4%	72.9%
Total Provincial	$22.3	13.2%	$29.7	14.4%	$35.1	16.8%	$58.7	27.0%	162.9%
TOTAL GOVERNMENT	**$86.9**	**51.2%**	**$107.3**	**52.2%**	**$123.3**	**59.0%**	**$122.0**	**56.1%**	**40.3%**
INDUSTRY									
Direct	59.2	34.9%	68.8	33.4%	56.7	27.1%	56.2	25.9%	-4.9%
Institutes	23.6	13.9%	29.5	14.4%	28.9	13.9%	39.1	18.0%	65.9%
TOTAL INDUSTRY	**$82.7**	**48.8%**	**$98.3**	**47.8%**	**$85.7**	**41.0%**	**$95.4**	**43.9%**	**15.3%**
TOTAL	**$169.7**		**$205.6**		**$208.9**		**$217.3**		**28.1%**

Appendix – Table 2. R&D Expenditures by Sector ($1986 millions)

	1982		1987		1992		1997	
	$	**%**	**$**	**%**	**$**	**%**	**$**	**%**
Forestry								
Federal	56.7	33.4%	69.4	33.8%	78.7	37.7%	57.4	26.4%
Provincial	20.6	12.1%	27.5	13.4%	32.7	15.7%	56.3	25.9%
Industry	3.9	2.3%	4.6	2.2%	4.1	2.0%	5.0	2.3%
Total Forestry	**81.2**	**47.8%**	**101.5**	**49.4%**	**115.5**	**55.3%**	**118.8**	**54.6%**
Wood Products								
Federal	7.9	4.6%	8.2	4.0%	6.7	3.2%	3.9	1.8%
Provincial	0.4	0.2%	1.0	0.5%	1.3	0.6%	2.2	1.0%
Industry	8.3	4.9%	11.4	5.5%	9.7	4.7%	14.4	6.6%
Total Wood Products	**16.6**	**9.8%**	**20.6**	**10.0%**	**17.7**	**8.5%**	**20.5**	**9.4%**
Pulp and Paper								
Federal	–	–	–	–	2.8	1.3%	2.0	0.9%
Provincial	1.4	0.8%	1.1	0.5%	1.0	0.5%	0.1	0.1%
Industry	70.5	41.6%	82.4	40.1%	71.8	34.4%	76.0	35.0%
Total Pulp and Paper	**71.9**	**42.4%**	**83.5**	**40.6%**	**75.6**	**36.2%**	**78.1**	**36.0%**
TOTAL	**169.7**		**205.6**		**208.9**		**217.3**	

Federal = CFS + NSERC (current survey).

Provincial = BC + Alberta + Ontario + Quebec (current survey).

Industry = Statistics Canada data (*estimates* used for 1982 and 1997).