FOREST BIOTECHNOLOGY IN CANADA: Analysis of Intellectual Property Rights and Protection of Higher Lifeforms

by

Steven Globerman
Department of Economics
Simon Fraser University
Burnaby, B.C.   V6K 1K7
Tel. 604-291-3711
Fax   604-291-5944

and

Ilan B. Vertinsky
Forest Economics and Policy Analysis Research Unit
University of British Columbia
468 - 2206 East Mall
Vancouver, B.C. V6T 1Z3
Tel. 604-822-3886
Fax 604-822-6970

March 1995

This study was funded by the Intellectual Property Policy Directorate, Industry Canada as part of a research initiative to develop a Canadian policy on the patenting of biotechnology, including higher lifeforms. The study represents the opinions of the authors who are solely responsible for its contents. It does not necessarily represent government policy.

ACKNOWLEDGEMENTS

The authors thank Marie-France Lamarche, Natural Resources Canada, Jock Langford and Geoffrey Oliver of the Intellectual Property Policy Directorate, Industry Canada for many helpful comments on earlier working papers. We would also like to acknowledge the helpful insights and information provided by Murthi Anishetty, John Barton, Calvin Bey, Mark Cantley, W.M. Cheliak, David Darr, Jarilyn Dupont, J. Engels, Jose Esquinas-Alcazar, Deborah Hurley, Masa Iwanaga, Stanley Krugman, Rory McAlpine, Barbara Martin, K. Mehta, John Miranowski, Michael Oborne, Kevin O'Connor, Daniel Rahier, Maria Raletich-Rajicic, Kare Ringlund, Albert Saint-Rémy, David Simpson, R.B. Singh, Valerie Sisson, Dick van Sloten, Ben Sutton, David Thomas, and Agnete Thomsen. All remaining errors of omission and commission are solely attributable to the authors.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

- The government of Canada intends to develop a policy on the patenting of higher lifeforms. This study is one of several sectoral studies funded by the Department of Industry to assess the impacts of patenting plants and animals. This study focuses on the potential impact and desirability of patenting multicellular organisms for application in forestry. It excludes from the analysis important biotechnological process innovations which do not involve, or have the potential of involving, innovative multicellular organisms. Biotech process innovations are already patentable subject matter and therefore excluded from this research project.

- Specific objectives of the study include:

  (1) an evaluation of the economic effects of alternative Intellectual Property (IP) policy regimes on participants in the domestic forestry sector including private forestry companies, public research institutions, manufacturers and consumers; (2) an assessment of Canada's strategic interests in the forestry sector against the background of international competitive developments, and (3) an evaluation of the likely rate and direction of technological change and economic growth in the forestry sector.

The Forest Products Sector

- The potential importance of the forestry biotechnology IP regime is underscored by the significance of the forest products sector to the Canadian economy. Forests are one of Canada's major economic resources, accounting for nearly $50 billion worth of shipments in 1993, along with $20 billion of exports and over 700,000 jobs. They are also a vital element of many local and regional ecosystems.

- Canada has a dominant position in exporting softwood lumber. It is also a highly visible exporter of wood pulp and newsprint. Canada's participation in the forest products industry is concentrated at the low value-added stages of the industry. Therefore, development in biotechnology affecting producers of forest products will have an asymmetric influence on Canada depending upon the precise nature of these developments. In particular, developments influencing production conditions in the low value-added stages will have a disproportionally important impact on Canadian producers, whereas developments influencing production conditions at other stages will primarily impact Canada as a consumer of forest products.

- Canada's profile as a large producer of downstream forest products is somewhat idiosyncratic compared to other large producers, in that, for most segments it is a much larger producer than consumer. This suggests that Canada's economic interests in forestry biotechnology are likely to reside in developments which enhance the producers' surplus rather than the consumers' surplus.

- A number of ongoing significant changes in the external environment of forest products firms are eroding their traditional sources of competitiveness. Some of these changes include: (1) increasing environmental sensitivities on the part of consumers affecting demand for Canadian products (e.g., increasing preferences for recycled paper). (2) Increasing competition to high quality wood from various sources such as engineered wood products, wood products made of fast growing lumber from softwood plantations, steel, plastics, etc. (3) Emergence of new inexpensive fiber suppliers. (4) Increasing wood costs associated with environmental regulations and tighter government controls on forest practices.

- To mitigate the erosion of their competitiveness, Canadian forest products firms require process and product innovations that permit product differentiation. In markets where they face inelastic demands, innovations which expand supply will not contribute to producers' surplus (and will thus lower the welfare of Canadians).

- The improvement of trees through biotechnology may offer the means for Canadians to preserve their comparative advantage in producing higher quality fiber. Up to the present, however, the process of tree improvement has predominantly involved classical genetic techniques. The use of vegetative clones is increasing, while somatic clonning (i.e., the production of engineered seed-like clones) is largely in the R&D phase.

<u>Seeds and Biopesticides</u>

- A vast majority of harvested lands in Canada are largely left for natural regeneration. The use of seeds has increased in the past two decades in response to government reforestation programs. Governments are the dominant actors in the production of seeds in Canada and as the owners of 95% of commercial forest land may prescribe what types of seeds are used. The tenure systems in Canada shape the incentives of private firms to invest in improving seeds, using improved seeds and deciding what kind of improvements to "buy". Insecurity of tenure reduces the incentives of firms to pay for improvements which provide only long term benefits. Indeed, Canadian forest products companies operating on public lands have an interest in short term "insurance" types of improvements (i.e., those improvements which protect the forest in the short run and thus protect harvesting rights). This bias is especially strong if the costs of protection accrue to the forest company.

- There is a fairly active trade in tree seeds from Canada and the U.S. to Europe and Asia (as well as a limited amount of trade from the Pacific Northwest to B.C. of Douglas Fir seeds). The economic importance of seed exports is, however, rather low.

- There is a well developed market for biopesticides for forestry applications. The market is highly concentrated. The major class of biopesticides which is used is based on *Bacillus thuringiensis* (B.t.) but there are no significant Canadian firms in the biopesticide market.

- The demands for biopesticides is increasing in response to environmental concerns and environmental regulation. The projected sales of B.t. pesticides by the year 2000 are about $270 million. Clearly some of this demand might shift from B.t. based pesticides to other types of biopesticides.

Biotechnology in Forestry

- Commercialization of the "new" biotechnology in terms of research and the development of products and services is less than twenty years old. The areas of application reflect both economic factors and the ease of the applications themselves.

- There are several broad (but not mutually exclusive) areas of application of biotechnology in the forest products sector: (1) tree improvement, (2) control of pests, and (3) improvement of industrial processes and bioremediation. Tree improvement and control of pests are the areas where there is a significant potential for innovations involving new multicellular organisms (and thus are the foci of our analysis).

- The relative difficulty of altering trees (compared to many annual plants) and the long horizons involved in receiving payoff from investments in tree improvement have meant that the task has received relatively little attention and funding to date. The growing pressures on forest land to meet demands, and the shrinking land base of the forest, are stimulating scientific and commercial interest in the subject.

- Some tree improvement strategies focus on enhancing quantitatively pre-existing traits, while others seek to introduce to the tree, traits that do not exist naturally. Biotechnology facilitated the former and made, through the use of recombinant DNA techniques, the latter strategies possible. Successful examples of the introduction of new traits which are available now include insect resistant poplars. In the next decade, similar innovations involving pest resistant and herbicide resistant plants are expected. Manipulation which involves several genes is less likely in the near future (though as gene mapping of impartial species of trees becomes more complete, better targetting of gene transfers to achieve traits that involve more than one gene will become possible). Another line of research that is being pursued, and which is likely to result in commercialization within a decade, is the modification of lignin biosynthesis that may reduce significantly the costs of pulp production.

- Many of the tree improvements involve a combination of classical breeding with biotechnology. This means that one must consider in the analysis of IP protection the complex relationships that exist between potential claims of breeders for the original improved stock, the rights for further improvements and the rights to the processes for generating somatic seeds.

- There are geographical constraints on the use of improved seeds although tolerance zones vary by species and type of improvement. These are also important considerations when analyzing the needs for IP rights protection.

- Current technological advances are outstripping the ecological knowledge that is required for development of more potent biopesticides. While the use of multicellular organisms for pest control is being experimented with, its commercial potential is limited by both economic and ecological concerns.

- There are several features of the international supply of biotechnology R&D and derived products: (1) the important role played by governments and public sector institutions (mainly universities). This means that a significant share of research in biotechnology is not driven by immediate commercial prospects. (2) Dual structure in North America, consisting of large diversified companies and small dedicated biotechnology companies which account for a significant share of the innovations. The existence of the small companies depends on their ability to protect the fruits of their research and signal their existence to the market. Indeed many small companies focus on the development of new patentable products and processes with the intention of selling the patents or their shares to larger firms.

- Some of the characteristics which affect innovation in forestry related biotechnology are: (1) The present value of expected profit from inventions is relatively low, so the prospects of private funding are not significant, (2) many of the research results (especially in the field of somatic seeds) do not have a universal application and often require a close relationship between the producers of the biotechnology and the users, (3) while the basic research elements of the application of biotechnology to forestry are well known, the "art" of processing and preparation of proprietary products is often protectable by secrecy.

The Economics of IP Rights Protection

- The design of patent law is fundamentally concerned not simply with prompting original innovations but rather with promoting the overall net benefits of the stream of primary and secondary innovations linked to the R&D activity. From a social welfare perspective, rewards to patents should be set so that the social benefits of an additional invention exactly equal the social costs.

- Two basic dimensions characterize the design of IP rights protection: length of time for which the underlying intellectual property is protected and the breadth of coverage of the protection.

- Different IP regimes or substitutes exist that provide for various degrees of protection in terms of time and scope, such as Plant Breeders' Rights and trade secrets.

- Because of the complexities and uncertainties surrounding IP policy, policymakers face two types of potential errors: (1) they can be overly generous in rewarding patentees which will delay benefits to consumers and encourage "patent races" which can be wasteful, (2) they can fail to reward patentees adequately, which will reduce inventive activity and deprive society of the entire flow of benefits associated with specific foreign inventions.

- The patent regime may have important consequences for economic efficiency if it encourages or discourages the earlier publication of research findings. Early publication may reduce duplication and stimulate new promising lines of research. Stronger patent protection may encourage firms to patent and disclose their inventions rather than rely on trade secrets; however, patenting may discourage researchers from publishing until the patent is filed and published.

- In domains where the inventive activities are closely related to basic scientific research, and where the most likely inventors for the foreseeable future are universities, government laboratories and other non-profit research centers (as is the case for example in the domain of forestry biotechnology), the negative consequences will be muted if patent authorities err on the side of providing too low a reward to patenting. In other words, there is a stronger argument for limiting the scope of patent protection, all other things constant.

- If the commercial benefits of an invention are realized only over a very long period of time, patent protection may be relevant, but only if the authorities are willing to grant relatively long patent terms. Even then, the present value of the returns may be relatively low, so that strengthening or weakening patent protection has little influence on inventing behaviour, on the margin. What seems most likely in cases of long-gestation technologies is that universities, government labs and the like will be the major sources of research.

- The stronger the patent protection granted on invention, the larger the surplus captured by the patentee. The weaker the protection, the larger the surplus captured by producers and/or consumers. If all participants are domestic residents, national surplus is enhanced by weaker patent protection. If consumers (producers) are foreigners, national surplus might actually decline (increase) with weaker patent protection.

- If foreign governments have implemented strong patent protection regimes any individual country proposing a weak regime courts retaliation. On the other hand, if the specific area of scientific activity is relatively specialized and not of great interest to other countries, retaliation may not necessarily be automatic or severe. In this case, a small country such as Canada is almost certainly likely to benefit from a weak patent protection regime, since it will benefit disproportionally from avoiding the payment of royalties to foreign patentees.

- Encouraging post-patent competition is generally preferable to discouraging such competition, especially when there is a relatively diverse range of potential applications for the relevant technologies and when the potential commercial applications are broad-based and difficult to predict *ex ante*. This suggests that the scope of patent protection should be relatively limited. On the other hand, if the technology being developed is specific to narrowly defined applications that are readily identifiable at the outset of the innovation process, a broader scope of patent protection might be appropriate to discourage competitive duplication of innovation in the post-patent period; especially if inter-firm licensing is problematic for one reason or another.

The Economics of Forestry Biotechnology Patenting

- Commercial activity in forestry biotechnology is much more limited than in medical or agricultural biotechnology. Government and other publicly funded institutions continue to be the main players in biotechnology applications outside the medical and pharmaceutical products sectors. Moreover, the outlook is that this will continue to be true for the foreseeable future in selection and improvement of forest tree species.

- Time will remain a major constraint in the progress of tree improvement programs. The long breeding and testing processes which are required for commercial applications make tree improvement more difficult, costly and uncertain compared to the improvement of many agricultural crops. Similarly, the high uncertainties involved in the research and development process reduce the commercialization potential of activity in this area, particularly since lower risk, more "conventional" breeding and improvement techniques are available. Another factor which has been found to discourage commercial R&D by private producers, especially in the plywood, sawmill and pulpmill areas, is the competitive level of production and rapid transfer of benefits to consumers. To some extent, vertical integration in the industry mitigates some of this concern; however, the relatively atomistic organization of the wood products segment of the industry suggests that producers will have relatively short time horizons and limited amounts of capital to perform long-term R&D projects.

- Genetic engineering is likely to expand the range of microorganisms that can be used as delivery systems for biotoxins. Great interest is now shown by researchers in the introduction of viruses as means of delivering toxins to insects and a patent in this area was recently granted to the American company Monsanto. The use of larger organisms as predators to control insect population is also being experimented with. The use of multicellular organisms for this purpose, however, is limited by both economic and ecological concerns.

- The commercial outlook is more immediate yet in the case of applications of biotechnology to improving production processes in the pulp and paper industry. While this interest is largely driven by environmental regulations imposed by governments, the likelihood is that such interest will continue.

- There are distinctive characteristics of forestry biotechnology which suggest that, in the short-run at least, the risks of erring on the side of weak patent protection are relatively low. The present values of expected profits from inventions with long terms to payoff are relatively low, so the prospect of private funding is not significant, in any case. Patent protection with normal terms to maturity will not change this imperative. Moreover, patents may not be as important in the protection of intellectual property as they are in other biotechnology applications. Relevant notions here include the following observations: (i) while the basic research elements of the application of biotechnology to forestry are well known, the "art" of processing and preparation of products is proprietary and is often protectable by secrecy; (ii) many of the research results (especially in the field of somatic seeds) do not have a universal application and often require a close relationship between the producers of biotechnology and the users (e.g., forest products companies, nurseries, etc.). This also implies lower risk that the technology developed can be readily appropriated for use by other firms. This conclusion may be less appropriate in the case of biopesticides than in the cases of improved seeds and bioprocessing. The market for biopesticides is well developed with a significant presence of large diversified companies that produce both chemical and biological pesticides for forestry and agriculture. In this market, the role of governments in funding and producing applied research is rather minor and commercial imperatives are fairly immediate. Hence, in the case of biopesticides in particular, other factors conditioning the welfare impacts of patenting may be of particular relevance.

- Review of the institutions involved in seed forest biotechnology research points to limited pre- and post-patent competitors, as well as the prominence of government funded R&D. Research on somatic seed is limited at present to a few organizations that specialize in regional-specific species. An implication is that pre-patent competition may be limited. Furthermore, at least in this area of research for the foreseeable future, patent protection in any country is likely to protect the intellectual property of local R&D performers.

- In biopesticides for forestry applications, four companies supply 92% of the global market demand. There are no significant Canadian players in the market.

- The relevance of patent protection in Canada to forestry biotechnology R&D is moot given the small number of Canadian R&D performers, as well as the dominance of government and publicly funded projects in the area. Potential commercial players, however, require patenting, since access to investment capital is often contingent on intellectual property protection.

- The role of governments as the dominant owner of forest lands means that any "economic rent" to users of biotechnological innovations, can be captured. Given that users are likely to be forest products companies, governments can appropriate the commercial benefits embodied in improved trees through higher stumpage fees. In practice, such rent-capture may be imperfect and some residual benefits can accrue to forest products firms.

- The demand functions that Canada faces for its major commodity exports are inelastic in the short and medium term. Innovations which increase exports are likely to result in price and revenue decreases. While producers (domestic) surpluses may decline, the benefits to consumers will accrue mainly to foreign consumers. In the long run one must consider the effects of higher prices on the introduction of substitutes. Canada with a large inventory of forest resources has a strategic interest in preventing price ranges that induce permanent substitution. Indeed environmental regulations in Canada and the U.S. have already pushed lumber prices to levels which may provide incentives for builders to change construction technologies and substitute for some of the wood products used in construction. Higher fibre prices combined with environmental regulation and public demand for greener products, have led to a higher use of recycled fibre. Thus innovation which increases forest productivity (e.g., improved trees with higher growth rates) should be encouraged if a long time horizon is considered for social welfare calculations. Unfortunately because of the existing system of incentives rooted in the dominant tenure systems and the public ownership of the resource, IP protection policies are not likely to stimulate Canadian private sector innovations that lead to improved forest productivity. Innovations that are targeted to short term cost cutting in forestry and processing, insurance and product differentiation are likely to result in improved social welfare. Such innovations are likely to be stimulated by higher level of IP protection, though the specificity of innovations given differences in the resource endowment between regions may make such protection less necessary.

- For the foreseeable future at least, participants on the "supply side" of the forestry biotechnology market (defined to encompass biopesticides and herbicides) will tend to be relatively specialized in terms of their innovation activities. Moreover, they seem to be focusing on problems particularly relevant to local users, so that the benefits of their innovation activities tend to be concentrated within specific segments of the industry. All of this suggests that innovators in this area may be able to internalize more of the benefits than is true in the case of innovation, more generally. In addition, those benefits not captured by local producers may be captured by local users, and will be retained by local users to the extent that the latter enjoy market power in the downstream markets in which they operate. As such, Canada may not have strong reasons to rely upon patent protection as a vehicle to promote forestry biotechnology.

- Since Canadian producers as a whole are not pure price takers in softwood lumber, pulp and newsprint sectors cost reductions stemming from innovations will not necessarily be passed completely through to consumers the bulk of whom are non-Canadians. Innovations which facilitate product differentiation will yield the bulk of the benefits to the producers. In the broad segments of the industry which face competitive markets final consumers (mainly foreigners) will be substantial long-run beneficiaries of competitive innovation in the industry.

- Balancing the different economic impacts of strong IP protection regime in the forestry related biotechnology sector and considering only economic arguments, the analysis provides a weak case for a strong domestic patent protection regime for forestry biotechnology. The economic arguments suggest that incentives to perform forestry R&D are influenced more strongly by ownership arrangements in the industry and by patent regimes elsewhere than by the patent regime in Canada. On the margin, some additional R&D in activities such as biopesticides might be stimulated by stronger domestic patent protection; however, offsetting this consideration are the higher prices for patented products that would be paid by Canadians. Since the bulk of biotechnology R&D in these activities is done by foreign firms, the "balance of trade" for Canada is likely to be worsened by stronger intellectual property protection.

Other Considerations in Patenting Living Organisms

- Arguments against patenting living organisms can be raised on a variety of grounds that the economic paradigm fails to consider. They include:

  Environmental considerations: Some opponents of patenting living organisms argue that environmental protection policies are not well developed to deal with such innovations. Limiting IP may slow the innovation process and consequently result in a smaller probability of environmental harm. Another argument against strong patent protection of living organisms is based on threats to biodiversity. It is argued that strong protection imposes constraints on the free flow of genetic materials and provides incentives to reduce genetic variation.

Theological and moral arguments: Some arguments especially directed at the patenting of transgenic animals are raised on the basis of metaphysical and theological concerns, including arguments that patenting promotes a materialistic conception of life and raises issues of the integrity of species and the sanctity of human life. Others focus on issues of animal suffering and inappropriate control over animal life.

Equity considerations: Some advocates against strong patenting of living organisms raise questions of international and domestic equity. These arguments are especially targetted at the patenting of useful genes found in nature. It is argued that farmers and consumers, especially in less developed countries, may have to pay royalties on products that are based on their own biological resources and knowledge.

Implementation problems: Some objections to the patenting of multicellular organisms stem from practical implementation problems or the high transaction costs involved (e.g., the need to develop appropriate depositories when other means of description of a new organism are inadequate).

High Costs of Enforcement Considerations: High costs of enforcement and uncertainties with respect to claims of patents involving new organisms create opportunities for firms with "deep pockets" to engage in strategic litigation using the patent law to deny others their rights to the fruits of their R&D or to pursue opportunities for invention.

- Objections which are based on ethical and metaphysical arguments must be left to the political arena and the courts. Some of the objections are based on false scientific assumptions or perceptions (e.g., protecting the integrity of species) while others are concerned with potentially inappropriate use of innovations and public risks that can result from such use. With respect to the latter, we argue that one must not confuse laws which settle property rights to innovations and laws and regulations which control their production and use. These objections to patenting life are based on the belief that by reducing the level of protection for a class of innovations, one will reduce the incentive to innovate, the rate of innovation and the risks associated with the innovation. In "science push" innovative sectors such as biotechnology, this direct form of risk reduction is highly ineffective. Even if the rate of innovation declines, there will not be effective control of the type and use of the innovations which occur. Indeed scientific curiosity may lead to inventions that commercial common sense may reject. Lack of IP protection is likely to increase secrecy and reduce the ability of society to monitor innovations and their consequences. Lack of information may delay regulatory moves to protect society or even make them impossible or impractical. Thus, direct and well targeted regulation of the use and production of innovations provides more effective protection and is more efficient than indirect control through IP protection policies. Other objections (e.g., the equity distribution and biodiversity concerns) can be dealt with through a modification of patenting laws.

- Choice of IP protection policies is influenced by the evolution of legal doctrines in other countries. The U.S. provided in the past decade a benchmark for the developed countries in the protection of living organisms - all multicellular organisms, with exception of humans, may be patentable as long as there is human intervention. In a majority of countries, mainly the developing countries, there are doubts about the precise nature of protection available for living material. Many developing countries expressly exclude plant varieties from patent protection, yet at the same time do not offer a special plant variety protection. In many developed countries (e.g., most countries in Western Europe) plant varieties are excluded from patenting, but the trend is to allow patenting with respect to claims pertaining to categories of plants broader than varieties. Similarly, court decisions have interpreted the European Patent Convention exclusion of "plant and animal" varieties not to exclude animals in general, but rather only animal races. In Canada, the current law does not exclude the patenting of animals or plants.

- A shift from the public sector to the private sector of efforts to improve genetic materials used in agriculture and difficulties of providing IP protection for traditional breeding activities under patent law led to the emergence of plant variety protection mechanisms. In their design these mechanisms reflect a compromise between the need to give breeders some means for appropriating benefits from their improvements of genetic stock, while ensuring continuing access of other breeders to improved materials so that the improvement process will continue. Breeder's rights protection is one of the few forms of intellectual property protection that has been shown to increase innovation.

- Recent revisions to the International Convention for the Protection of New Varieties of Plants (the UPOV Convention, 1991) have broadened the protection offered by the Convention to breeders. It enlarged the scope of rights to extend them *inter alia* to all production of propagating material, while preserving the availability of improved varieties to breeders for the development of new varieties. It requires a breeder of a variety which is "essentially derived" from another protected variety to obtain authorization of its breeder. It abolished the prohibition of double protection. It extended breeder's rights to harvested material. It requires all members to protect variety of all plants, genera and species. Canada has ratified the Convention but has not yet amended its Breeder's Rights Act to conform to the requirements of the Convention.

- The degree of freedom in choosing an IP protection policy which is optimal from a domestic point of view is constrained by international agreements and by fears of retaliation. These limit the opportunities of a country to benefit from "free rides" by adopting a lax IP protection policy. Thus, for example, changes in Canadian policies with respect to protection of biotechnology innovations must be in harmony with the Paris Union Convention, the Budapest Treaty (once ratified by Canada), the NAFTA, the GATT/TRIP and the U.N. Convention on Biodiversity. In addition, Canada must consider obligations (though not legally binding) under its FAO undertaking.

- High transaction costs involved in obtaining and defending intellectual property rights may encourage "strategic litigation" which may reduce the efficiency of the innovation process. Plant variety protection which typically involves significantly lower transaction costs to obtain and is easier to defend reduces the incentives to engage in strategic litigation.

Conclusion

There is almost universal acceptance of patenting microorganisms. The trend internationally, though less consistent, is to permit the patenting of multicellular organisms but to tighten regulation of their introduction to the environment and their eventual use. With respect to the forest product sector, patenting policies with respect to animals are of little economic consequence. The use of multicellular organisms as effective agents of pest control is not likely to assume a significant role for the next decade. Indeed, research on biopesticides based on bacteria and viruses is dominant. The relative ease of producing microorganisms compared to the difficulty of raising multicellular animals is likely to keep research on biopesticides focused on the former.

IP protection of plants is already available in Canada (and most of the industrialized countries) through breeder's rights protection mechanisms (which following the implementation of the 1991 Act of the UPOV Convention will provide higher levels of protection). It is our view that from a purely domestic perspective, once the Breeder's Rights Act is revised to meet the 1991 Convention requirements, it will provide an appropriate balancing of concerns for maintaining the flow of germplasm to breeders while providing sufficient incentives to innovators. Strategic arguments for stronger patenting may be made on the basis of Canada's future ability to attract investment in Canadian biotechnology companies, however, these arguments are not very compelling. The regulatory environment, access to venture capital markets and the scientific and human capital resources available in Canada are probably the dominant factors in attracting innovative companies to Canada. IP protection policies will play a relatively minor role in the location decisions of biotechnology companies.

The need to ensure that the chosen IP policy is consistent with obligations under the relevant international treaties and agreements is an important consideration.

1.0 INTRODUCTION

The government of Canada intends to develop a policy on the patenting of higher life forms. To this end, Industry Canada has commissioned studies of the potential impacts of patenting animals and plants in various industries and sectors of the Canadian economy. This study focuses on the potential impact and desirability of patenting higher lifeforms (multicellular organisms) for application in forestry, specifically seeds and biopesticides. "Process" innovations in the forest products sector (e.g., using new types of enzymes for pulping) which do not involve (and do not have the potential for involving) innovative multicellular organisms are excluded from consideration in this study. We do consider, however, the improvements which may change the "fiber qualities" of the trees, and thus lead to changes in downstream products and processes.

The basic objective of the research undertaken for this project is to provide economic advice on the optimal Canadian strategy for intellectual property (IP) protection in the forest products sector. The broad policy objectives are to encourage rapid innovation and technology dissemination coupled with wide availability of new biotech products and processes at competitive prices to Canadians.

Specific research objectives include: (1) an evaluation of the economic effects of alternative IP policy regimes on participants in the domestic forestry sector including private forestry companies, public research institutions, manufacturers and consumers; (2) an assessment of Canada's strategic interests in the forestry sector against the background of international competitive developments, and (3) an evaluation of the likely rate and direction of technological change and economic growth in the forestry sector.

As opposed to the United States, the doctrine of IP protection in Canada does not assume that all inventions which meet traditional criteria for patenting (i.e., those of utility, novelty, non-obviousness and a description of the subject matter which permits (skilled) other to reproduce it) are patentable. Microorganisms can be patentable if they meet the following conditions: (1) they must be new, i.e., they should not have existed previously in nature, (2) they must be useful, (3) they must be produced in sufficiently large quantities and possess uniform properties, (4) they must be sufficiently different from known species that their creation involves elements of inventive ingenuity, and (5) a description of the method of production must be provided with such clarity that others could reproduce it with fidelity. A deposit of a strain of the microorganism in a recognized depository may satisfy the description requirements.

Categories of patentability are identified in legislation and interpreted by the courts. The Canadian Intellectual Property Office then interprets the law based on the legislation and jurisprudence. Developing and presenting to the Government possible changes to legislation, including determining categories of patentability, is the responsibility of the Intellectual Property Policy Directorate.

At present, plant varieties cannot be protected by patents; however, plant varieties can be protected under the *Plant Breeder's Rights Act*. Only varieties from certain species (but not forest trees) are covered at this time. Canada ratified the 1991 Act of the UPOV Convention but has not yet amended the Act to conform with the Convention. When the Act is amended to conform with the Convention it will need to be extended to cover all species. To receive protection, varieties must meet a criterion of novelty which is less demanding then the patenting criterion.

Other attributes of the external legislative environment are also relevant to domestic policy initiatives. For example, changes in Canadian IP protection policies with respect to biotechnology innovations must be in harmony with the Paris Union Convention, the Budapest Treaty (once it is ratified by Canada), the North American Free Trade Agreement, the GATT/TRIP and the U.N. Convention on biodiversity. In addition, Canada must consider its obligations (though not legally binding) under its FAO undertaking.

The potential importance of the forestry biotechnology IP regime is underscored by the significance of the forest products sector to the Canadian economy. Forests are one of Canada's major economic resources, accounting for nearly $50 billion worth of shipments in 1993, along with $20 billion of exports and over 700,000 jobs. They are also a vital element of many local and regional ecosystems. In recent years, traditional forestry practices and economics have been challenged by environmental pressures on both the supply and demand sides of the market for wood products. Moreover, increasingly forests are viewed as serving a multiplicity of interests - as an ecosystem sustaining wildlife, as a local recreational resource for hunting, fishing, hiking and other sports, as well as a key factor in attracting tourism. These competing uses of the forest raise additional concerns about the potential for continuing to harvest the forests as int he past.

Against this background, forestry biotechnology can be seen as presenting both opportunities and threats to the Canadian sector. An important focus for research is, therefore, to identify the preferred IP regimes; i.e., regimes which leverage the benefits of the opportunities while mitigating the threats.

The study proceeds as follows. Section 2 discusses the importance of the forest products sector to Canada, as well as the industrial organization of the sector. Section 3 includes an overview of the seeds and pesticides sectors. Section 4 presents a detailed overview of biotechnology in forestry, as well as details about the structure of the biotechnology industry in Canada that specializes in forestry related innovations. In Section 5, a detailed economic analysis of IP Protection is provided. Generic economic issues are identified and discussed, and the resulting analysis is then applied to the forest sector. Institutional and legal considerations surrounding IP protection for forestry biotechnology are considered in Section 6. The final section of the paper (Section 7) presents conclusions and policy implications.

2.0 OVERVIEW OF THE FOREST PRODUCTS SECTOR

In this section we provide an overview of the major sectors of the forest products industry. This includes a brief statistical overview of the sizes of the major sectors, along with the identities of major producing and consuming countries. Since much of this material is both well known and relatively straightforward, most of the associated discussion concentrates on highlighting Canada's economic interests in the industry and drawing specific inferences, where possible, about Canada's interests in biotechnology developments. Before doing so, it is important to stress how important the forest products industry is to Canada. Forests are one of Canada's major economic resources, accounting for nearly $50 billion worth of shipments in 1993, along with $20 billion of exports and over 700,000 jobs. They are also a vital element of many local and regional ecosystems. The harmonization of environmental and economic considerations represents a major challenge for forestry policy over the foreseeable future.

2.1 Main Sectors

Figure 1 provides an overview of the vertical and horizontal linkages in the forest products industry. Table 1 reports data on the world production of forest products for selected years from 1980-1991. Several points might be noted in the data. One is the relative stagnation of the softwood lumber sector. While prices of timber have increased significantly recently, the availability of timber for cutting is declining contributing to slower growth of real output in the sector. As we shall highlight below, Canada is the world's major producer of softwood lumber. Hence, the sources of the observed stagnation, as well as the potential for change are of obvious importance from a Canadian perspective. A second is the relatively rapid growth of the paper and paperboard sector, especially specialty writing paper. We shall highlight Canada's small (absolute and relative) position in this sector of the industry. Many observers have identified the worrisome implications of Canada's competitive weaknesses in this sector of the industry. A third point to note is the faster growth of the particleboard and fibreboard sectors of the wood-based panel segment compared to the more traditional veneer and plywood sectors. The emergence and growth of new building materials has important potential implications for Canadian producers, especially those concentrating on the production of traditional building materials.

2.1.1 Canada's Position in the Industry

Tables 1 through 6 (in the annex) report statistics on worldwide production of forest products by major commodity aggregates. Again, we will merely highlight what we believe are the most salient characteristics of Canada's position in the international market. First, it is clear that Canada is a major exporter of specific forest products. For example, Canada accounted for almost 42 percent of total lumber exports in 1991. This primarily reflects Canada's dominant position in the exporting of softwood lumber (about 50% of world exports in 1991). The United States remains the single largest lumber importer, although it accounts for less than one-third of total lumber imports. While Canada is a relatively large producer of lumber on the world scene, it is smaller than a number of other countries, including the U.S. and the former Soviet Union.

Canada is also a highly visible exporter of wood pulp and newsprint. Indeed, it accounted for over 56% of all newsprint exports in 1991. Reflecting its small overall economic size, Canada's position as a producer of wood pulp and newsprint is more modest (in relative terms) than its position as an exporter. Nevertheless, Canada was the world's largest producer of newsprint in 1991 and the second largest producer of wood pulp. The United States was the dominant importer of newsprint reflecting, in part, its position as the world's largest consumer of newsprint. The United States is more self-sufficient in wood pulp which is reflected in the fact that the import market for wood pulp is more evenly balanced (than newsprint) between the U.S., Germany and Japan.

A second point which can be inferred from Tables 5 and 6 is that Canada is a relatively and absolutely small producer of paper and paperboard excluding newsprint. Using the data in Tables 5 and 6, one can calculate that Canada accounted for less than 4% of total world production of paper and paperboard (excluding newsprint) in 1991 and accounted for slightly less than 8% of total world exports of paper and paperboard products. These data confirm the well established fact that Canada's participation in the forest products industry is concentrated at the low value-added stages of the industry.

A third point which could be inferred from Canada's small overall economy is that Canada is a relatively and absolutely small consumer of forest products with the possible exception of wood pulp. The United States remains the single largest consumer of forest products, but its relative dominance in this respect is declining owing to faster economic growth in other regions of the world. In particular, the rapid growth in the demand for building materials and paper products in the Asian economies is noteworthy.

One can draw several inferences relevant to forest biotechnology from the data presented in Tables 2 through 6. Perhaps the most prominent inference is that developments in biotechnology affecting producers of forest products will have an asymmetric influence on Canada depending upon the precise nature of those developments. In particular, developments influencing production conditions in the low value added stages of the industry will have disproportionately important impacts on Canadian producers, whereas developments influencing production conditions at other stages will primarily impact Canada as a consumer of forest products rather than as a producer.

Given the potential importance of biotechnology to fibre stocks, it seems useful to consider the broad distribution of fibre stocks on a national basis. Table 7 provides estimates of fibre stock (in terms of thousands of hectares) on a broad continental basis, as well as for the major countries in the various continents.

South America as a continent has the largest total forested area and Brazil has the single largest forested area. Africa is another relatively large forested region; however, both are producers of tropical hardwood. Evidence indicates that elasticities of substitution between temperate and tropical wood products are significant but relatively low. This suggests that markets for tropical and temperate timber products are somewhat distinct. Hence, tropical producers of wood products may have some difficulty in penetrating the larger temperate market.

Producers of temperate wood compete more directly with Canada. The potential importance of the former Soviet Union is obvious from the table. It is not obvious how biotechnology will affect the competitiveness of the former Soviet Union; however, it is clear that if it does, Canada will experience an impact. Canada is the second largest potential producer of temperate wood products based upon raw forested land.[1] The United States is the third largest. Sweden and Finland have relatively small feedstocks compared to Canada and the U.S., but they both are still large exporters.

Some additional evidence on the potential national impacts of forestry biotechnology on both the production and consumption sides of the market is provided in Tables 8 through 11. Table 8 reports the eight leading countries from the standpoint of the production and consumption of sawn logs. To the extent that biotechnological developments influence the economics of activities downstream from the actual harvesting of fibre, producers and/or consumers in those downstream markets can expect to be impacted. The nature and distribution of those impacts obviously depend upon the nature of the specific development, as well as the resulting changes in the positions and slopes of the supply and demand functions; however, to the extent that a country is primarily a producer or a consumer of a downstream product, it is likely to have a different view of the development than a country that is "balanced" between production and consumption.

Looking at Table 8, we see that the United States is the world's largest producer and consumer of sawnwood. It is roughly balanced between production and consumption. The former Soviet Union is the second largest producer and consumer of sawnwood. It too is roughly balanced. Canada is the third largest producing country; however, it is only the eighth largest consumer. The large difference between Canada's production and consumption status suggests that Canada's interest in this sector is primarily as a producing nation rather than as a consuming nation. Interestingly, virtually all other countries represented in Table 8 are roughly balanced between production and consumption.

Table 9 reports similar data to Table 8 for wood-based panels. In this segment of the wood-products market, Canada is the sixth largest producing nation and the seventh largest consumer. Again, its size as a producer exceeds its size as a consumer, although it is a relatively small participant on both sides of the market by the standards of the market leaders. Again, most countries in the table are roughly balanced between production and consumption. Japan is a notable exception in this regard being a significantly larger consumer, as is China. Conversely, Indonesia is a relatively large producer.

Table 10 reports data on pulp for paper and waste paper for the leading producing and consuming nations. Canada is the second largest producer following the United States. While it is the fourth largest consuming nation, its production again substantially exceeds its consumption.

---

[1] Obviously, yields can vary depending upon a variety of factors. Hence, forested area is only suggestive of the potential supply of wood products production.

Conversely, consumption in the United States substantially exceeds production. China and Japan also consume well in excess of what they produce. Sweden and Finland are net producers of pulp but not nearly to the extent that Canada is.

Finally, Table 11 reports comparable data for the paper and paperboard segment. An even more striking net production imbalance is apparent for Canada. Specifically, it is the fourth largest producer (primarily reflecting newsprint production) but is not in the top eight of consuming countries. The top three producing (and consuming) countries are roughly balanced. Finland and Sweden share Canada's position as a net exporter, although the Scandinavian countries are absolutely smaller producers than Canada. It must be noted parenthetically that China's importance both as a producer and a consumer of paper and paperboard is increasing dramatically and can be expected to continue to grow in the future. China's interest in the importation of improved seed and its willingness to field test on a mass scale genetically engineered seeds makes it potentially an important consumer in the market for somatic seed.

In summary, Canada's profile as a large producer of downstream forest products is somewhat idiosyncratic, in that for most segments it is a much larger producer than consumer. This suggests that Canada's economic interests in forestry biotechnology are likely to reside in developments which enhance producers' surplus rather than consumers' surplus. By contrast, the United States is much closer to balance between production and consumption and is, therefore, more likely to have ambivalent interests. Japan's interests as a net consumer are likely to reside in favouring policies that promote consumers' surplus.

At least part of what will influence the distribution of efficiency gains (broadly defined) associated with forestry biotechnology is the market power of producers relative to consumers in different relevant markets. Moreover, within specific segments of the industry, the ability of individual producers to appropriate more fully the returns from their innovation activities will also depend, in part, upon their market power. It is therefore useful to review structural attributes of the different segments of the forest products industry with a particular view towards assessing the market power of producers.[2]

2.2 Industrial Organization Structure

In this section, we review the industrial organization of the forest products industry. Industrial organization is concerned with how structural features of an industry are ultimately related to the behaviour and performance of firms in that industry. Hence, an important emphasis in the relevant literature is on identification of structural features such as the market shares of leading firms, the size distribution of firms, entry and exit conditions, source of ownership, extent of horizontal and vertical integration and so forth.

[2] In so doing, we acknowledge that standard industry segment classifications do not necessarily correspond to relevant market segments; however, for purposes of exposition at a broad level of analysis, we need not worry overly about this distinction.

2.2.1 Implications of Industrial Structure

Before identifying and assessing important structural features of the various segments of the forest products industry, it might be appropriate to discuss why this information is potentially useful in addressing the ultimate research questions of interest to us. The motivating notion is that developments in forestry biotechnology, as well as the economic consequences of those developments, will be substantially influenced by the way that economic activity is organized in the sector. For example, the incentive of firms to engage in certain types of research will be affected by the nature of competition that they confront, as well as by the extent of their economic diversification. Similarly, the importance of intellectual property legislation to firms will depend upon, among other things, market structure characteristics such as concentration ratios, entry and exit barriers and geographic and product market diversification.

2.2.2 Economic Organization of the Canadian Industry

A profile of the Canadian industry is provided in Table 12. Several characteristics of the industry are obvious from the table. One is that the wood industry sectors of the overall forest products industry are relatively atomistically organized. Specifically, average establishment sizes are relatively small and concentration ratios can be presumed to be relatively low, as well. For example, the average value of shipments for logging establishments in 1991 was slightly less than $1 million. The average value of shipments was around $9 million for saw and planing mills, while the average value of shipments for veneer and plywood establishments in the same year was around $11.5 million. This is comparable to the average value of shipments by establishment for the category "Other Paper Products" (i.e. approximately $11 million). In contrast, the average size of shipments for pulp and paper establishments was close to $100 million. Pulp mills are substantially larger than mills producing paper and board products, attesting to the greater importance of economies of scale in the pulp sector.

A second point of interest is the change in average value of shipments over time by segment of industry. Specifically, in comparing the data for 1980 and 1991, we observe that the average sized logging establishment was actually smaller in 1991 than in 1980 (in current dollar terms). By contrast, the average sized pulp and paper establishment was about 32% larger in 1991 compared to 1980 - again in current dollar terms. In constant dollar terms, average size in the pulp and paper sector actually declined, as it did in veneer and plywood. One might tentatively conclude from these observations that economies of scale may have become relatively less important over time in the forest products sector compared to other determinants of industrial organization.

2.3 Economic Organization in Other Countries

Available data from various sources allow us to piece together a profile of the industrial organization characteristics of the forest products industry in other countries to compare and contrast with Canada.

2.3.1 Average Size

In particular, detailed capacity data are available for the pulp and paper segments of the industry. Table 13 summarizes 1991-92 capacity figures (in thousands of tons) for the paper and board and pulp segments for major producing countries. These data show that Canadian mills are relatively large by world standards, especially in the pulp segment of the industry.

Similarly, Canadian lumber mills are also large by international standards. For example, in 1992, the nine largest Canadian lumber companies averaged 115 million board feet per mill. In comparison, the largest eleven U.S. companies averaged 67 million board feet per mill (Wood Technology, 1993).

While the average sizes of mills in Canada are comparable to those in other countries, Canadian producers are relatively small firms by international standards. By way of illustration, there were 50 companies in 1992 that produced more than one million tons of paper and board, only four of which were Canadian-owned. Moreover, the largest Canadian company ranked only as high as 24th on the list (PPI, 1993). Whereas the average volume produced by these 50 companies (in thousands of tons) equalled 2,394, the average volume produced by the four Canadian companies was 1,583 (PPI, 1993).

In terms of sales, Canadian pulp and paper producers are smaller (in relative terms) than is suggested by physical output numbers. This reflects the fact that Canadian producers tend to concentrate on "commodity" products which typically have relatively low price-cost markups. Thus, the largest Canadian pulp and paper producer (by dollar of sales) in 1992 ranked only 44th on the list of the top 50 pulp and paper producers in the world. Moreover, the largest international producer (International Paper) was fully nine times larger than the largest Canadian producer.

It is difficult to present comparable sales data exclusively for wood and wood products activities, since large pulp and paper producers are typically integrated backward into the production of wood products; however, a comparison of the net sales of building products operations further underscores the fact that Canadian firms are small relative to their U.S. counterparts. By way of illustration, the 1992 net sales revenue from building products operations averaged US$ 1,721 million for the 10 largest U.S. companies. The comparable statistic for the 9 largest Canadian companies averaged Canadian $547 million. Given the average value of the Canadian dollar in 1992 (around US$.83), U.S. firms were almost four-times larger than their Canadian counterparts.

2.3.2 Concentration

Data on logging production in the United States and Canada support the view that it is a relatively atomistic activity. Specifically, data are available for total lumber production in Canada and the United States for 1992 along with the production of the largest North American companies (Wood Technology, 1993). The share of total output accounted for by the 8 largest firms is only around 19% which is well below a threshold that most economists would consider defines an oligopolistic market structure.

It is considerably more difficult to calculate concentration ratios for other individual segments of the wood products industries; however, it can be inferred that they are more concentrated than the logging sector. For example, the four largest producers of softwood plywood in the United States in 1992 accounted for about 54% of the total softwood plywood produced by the top 46 producers in the United States in that year (Wood Technology, 1993). In fact, this four firm concentration ratio calculated for a portion of the market is borderline for an oligopoly. In the context of all U.S. production of softwood plywood, it is suggestive of a market with relatively limited market power on the part of most producers. While we have not attempted to estimate similar market structure proxies for other building materials, there is no reason to think that the conclusions would be any different from those for plywood.

The heterogeneity of the paper and paperboard sector makes it difficult to calculate narrowly defined concentration ratios for this segment as well. Specifically, company data are generally reported for a broad aggregate of the company's activities. Hence, broadly based concentration ratios may fail to identify market power in more narrowly defined sectors. Bearing this caveat in mind, it can be inferred that over the broadly defined paper and board segment of the industry, concentration is relatively low. Specifically, the largest four firms in the world accounted for only 20% of the total output of the top 50 companies in 1992. The largest eight firms accounted for 34% of the total output of the top 50 firms in that year.[3] Taken by themselves, these concentration ratios suggest that paper and board producers do not enjoy significant market power.

2.3.3 Ease of Entry and Exit

Economists recognize that even relatively high levels of industrial concentration may be misleading indicators of producer market power if entry into an industry is relatively easy. Since difficulties in exiting an industry will be factored into decisions made to enter an industry in the first place, overall barriers to new competition consist of both entry and exit costs.

Specifically, ease of entry and exit is largely conditioned by the sunk cost investments required to participate in a market. Sunk costs are costs that cannot be expected to be recovered if the firm ceases to engage in the relevant set of activities. They are typically associated with investments in assets that are idiosyncratic or specialized to the activities in question. As noted

---

[3] These ratios are calculated from data reported in PPI (1993).

above, average establishment size in the wood industries segment is relatively small suggesting that idiosyncratic capital investment requirements are not likely to be a substantial barrier to entry in the relevant activities. Far more relevant is access to timber. In countries such as Canada, where timber cutting rights are allocated by the government, it is not so much sunk costs as government forestry policy that conditions ease of entry. Specifically, firms may be restricted in terms of entry or expansion because of direct limitations on the allowable amount of cutting that firms can do on Crown land. In fact, given environmental-related restrictions on logging activities in countries characterized by substantial private ownership of the forestry resource, most notably the United States, government policy is also arguably the single most important determinant of entry and expansion in the wood products sector.

Indirectly, therefore, perceptions by governments about the optimal rate of harvesting which, in turn, reflect competing public uses for the forest, environmental concerns and rates of depletion of timber stands, represent an important "exogenous" influence on entry conditions in the "upstream" segments of the industry. Environmental policies also are an important influence on entry and expansion decisions in the downstream segment of the industry. In particular, requirements to reduce and/or restrict pollution in pulp and paper mills adds an additional significant cost to the (largely sunk) capital cost requirements of this sector. Since it is often less expensive to build clean technologies in new pulp and paper mills than to modify polluting technologies in older mills, public sector environmental policies can affect the "exit" decisions of producers in this sector, as well as entry conditions.

2.3.4 Horizontal and Vertical Integration

Another characteristic of markets that economists frequently address is the extent of horizontal and vertical integration. One reason that this characteristic may be interesting is that it suggests the degree to which firms can "internalize" technological changes affecting the industry more broadly. That is, the more diversified the range of activities undertaken by the firm, the more likely it is that it can directly apply technological changes within its own production activities rather than having to license the use of the technology to other firms in order to realize financial benefits from innovation. All other things constant, this would presumably motivate the firm to do more innovation. On the other hand, high degrees of horizontal and vertical integration might reduce the number of independently owned firms capable of doing innovation. The adverse effect of having a smaller number of innovators might offset any stimulus to innovation associated with economies of scope as described above.

Vertical integration is a ubiquitous feature of the North American forest products industry. Unfortunately, it is not possible to summarize the nature and extent of vertical integration very easily, since different firms are integrated through different stages. Moreover, the degree of integration can be partial or complete in the different stages.[4] Suffice to say that major producers

---

[4] For a detailed description of vertical integration in the Canadian forest products industry along with explanations of the factors conditioning the observed patterns of vertical integration, see Globerman and Schwindt (1986).

of paper and board products are frequently integrated backward to include the logging activity. Conversely, major logging companies are less likely to be integrated through to the production of paper and board products; however, they are often integrated through the production and distribution of wood products (Cohen and Sinclair, 1991). During the decades of the 1960s and 1970s forest products companies integrated forward into distribution. Controlling distribution channels allegedly put a company closer to the end user and sensitized management to changing consumer needs. The emphasis on ownership of distribution channels was reversed in the 1980s, as recessionary conditions encouraged firms to focus on core production competencies (Cohen and Sinclair, 1991). However, there continues to be a consolidation of distribution capacity in both the wood products and pulp and paper segments of the overall industry.

2.3.5 Competing Groups

It is acknowledged by industrial economists that standard statistical approaches to classifying industrial activity are often misleading, in part because they define competing groups of firms too broadly.[5] That is, firms often compete in specific ways such that rivalry is relatively pronounced between subsets of firms within a conventionally defined sector, such as paper products, and relatively weak between other subsets. A fuller discussion of competitive strategies in the wood products industry is provided in the next main section of this report. In this subsection we highlight the nature of the strategic groups to which Canadian firms belong in the major segments of the forest product industry.

In fact, it is difficult to draw hard and fast boundaries around competing groups in different segments of the industry. For example, the wood and wood products segments can be subclassified by, among other things, the quality and accessibility of the fibre base, the target geographic markets for the products produced and the relative emphasis on price versus product features on the part of producers. Along these dimensions, several points can be made about the distinguishing features of Canadian producers. One is the access of Canadian producers to high quality, slow grown fibre. The Pacific Northwest is noted for especially high quality softwood lumber and, in this respect, competes most directly with other "northern" climates such as Scandinavia and the former USSR as a source of raw material. While harvesting capacity in southern hemispheric countries such as New Zealand and Chile is expanding, the primary species in those countries (radiata pine) is considered a low quality product best suited for general construction or other low-end uses (Cohen and Gaston, 1993). Canada's Northwest fibre species are also considered superior in quality to Southern Yellow Pine, although industry observers tend to consider the latter a closer substitute for Canadian softwood than is radiata pine.

A second distinguishing feature of Canadian producers is their relative emphasis on the U.S. market. For example, approximately 75% of Canadian exports of softwood lumber went to the United States in 1990. As recently as 1992, almost 60% of lumber shipments from British Columbia were destined for the United States. There is greater geographic diversification of

---

5 For a discussion of competing groups in the context of a model of entry and exit, see Caves and Porter (1977).

plywood shipments. In this case, sales to U.S. customers accounted for only 25% of all Canadian exports in 1990. Wood pulp exports are somewhat more concentrated; i.e. around 48% of Canadian exports go to the United States. But fully 84% of Canadian newsprint exports are to the United States, based on 1990 data.

U.S. reliance on Canadian exports varies from segment to segment. For example, Canada accounted for virtually all U.S. imports of softwood lumber in 1990; however, Canada accounted for only about 7% of U.S. plywood imports. In 1990, Canada was the source of 88% of U.S. imports of wood pulp and almost 98% of U.S. imports of newsprint. Hence, it does not seem too gross a simplification to argue that Canadian producers compete as closely with U.S. producers in specific activities as they do with each other.

Outside of the United States, Canada sells significant amounts of softwood lumber to the United Kingdom and Japan. In the United Kingdom, Canadian producers face competition primarily from Scandinavian producers and producers in the former USSR. In Japan, Canada's primary competitors are U.S. producers. In wood pulp, Canada exports significant volumes to Europe and Japan. Again, the Scandinavians are the chief competitors in Europe and the Americans are the chief competitors in Japan. Hence, even on a broader geographic basis than North America, Canada competes in a close "strategic group" with U.S. producers.

A third distinguishing feature of Canadian wood products producers is their competitive emphasis on a high degree of product standardization and product quality control (Cartwright, 1993). This emphasis at the production stage of the sector augments the quality distinction enjoyed by Canadian producers as a consequence of the fibre stock. The emphasis also distinguishes Canadian producers from those in developing countries whose primary emphasis is on low price exports, as well as producers from developed countries that concentrate on highly "engineered" lumber products.

It is a bit harder to distinguish strategic groups and the position of Canadian firms in those groups when considering the pulp and paper sectors (including newsprint), in part because fibre stock quality is a less important characteristic relative to other considerations. As noted earlier, Canadian output is primarily concentrated in pulp and newsprint. It is a very minor competitor on a world-wide basis in finished paper products.

Certainly one requisite key success factor for competing in the production of pulp and newsprint is access to relatively economical sources of fibre. In this respect, emerging pulp producers in southern hemispheric countries such as Indonesia, Chile and Australia can compete against Northern hemispheric producers, all other things constant, given the relatively ample stocks of suitable fibre in those countries (Stanbury and Vertinsky, 1991). Indeed, an emerging relevant distinction in terms of source of fibre is between virgin and recycled fibre. Both legislative trends and consumer preferences in developed countries are favouring the use of recycled fibre in downstream processing. In this respect, Canadian producers are in a different strategic group from their U.S. and European counterparts given the very limited availability of economical recycled fibre in Canada.

In the manufacturing of commodity products such as pulp and newsprint, producers tend to emphasize the exploitation of economies of scale. However, there are apparently opportunities to engage in product differentiation even in these commodity sectors. For example, Japanese producers of newsprint have apparently been able to customize their output to some extent to meet the specific needs of downstream buyers (Ursacki, 1992). Nevertheless, cost and price tend to be the dominant competitive instruments in the pulp and newsprint sectors. As in the case of wood products, there are geographical market strategic groups in the pulp and newsprint sectors. Canadian producers again tend to concentrate on the U.S. market, especially in the newsprint sector; however, significant volumes are also exported to EC countries where Canadian producers face competition from Scandinavian producers, in particular, as well as American producers. On the pulp side, Japan is Canada's second-largest pulp market. Competition in the U.S. market includes U.S. producers and, looking to the future, increasingly from South American producers such as Chile and Brazil.

2.4 An Overview of the Strategic Environment

In this section, we identify major recent developments in the external and internal environments of the forest products industry that potentially bear upon the competitive position of Canadian firms. Developments in the external environment encompass changes in underlying cost and demand conditions facing producers in various segments of the industry. Developments in the internal environment encompass changes in corporate and competitive strategies on the part of producers.

2.4.1 External Environment

A number of ongoing and significant changes in the external environment have been cited in the literature.

1) Increasing environmental sensitivities on the part of consumers. This particular development has been manifested in a growing militancy on the part of environmental groups about cutting practices and an emerging preference in both public and private sector organizations for recycled "feedstock" rather than virgin fibre. Most recently, it was reported that MacMillan Bloedel lost contracts with two major producers of tissue paper, Scott and Kimberly Clark, allegedly because of clear-cutting practices by MacMillan Bloedel. The implication of this development is relatively clear. As noted above, one of Canada's major competitive advantages is access to high quality virgin fibre. To the extent that consumers increasingly prefer recycled feedstock, this advantage will be increasingly reduced.

2) Traditional lumber products are facing increasing competition from various sources including engineered wood products that use less lumber, wood products made of fast-grown lumber from softwood plantations and non-wood products made from steel, aluminum, plastics and so forth (Cartwright, 1993). Again, the implication is that Canada's reliance upon high quality

wood fibre as a key success factor in the wood products segment is becoming increasingly tenuous.

3) The impact of economic reforms in the former Soviet Union is a big unknown with potentially profound consequences for the forest products industry. In particular, it is a major potential supplier of relatively low-cost softwood fibre. To be sure, there are a variety of major obstacles to the emergence of this region as a major supplier including the geographic dispersion of forests, the expense of effective reforestation efforts and a shortage of transportation capacity (Stanbury and Vertinsky, 1991). Nevertheless, the implication again is that one of Canada's underlying competitive strengths is in danger of being eroded.

4) Emerging economies in Asia including China and South Korea are increasing and diversifying demand for timber including the substitution of softwood lumber for hardwood. This development suggests that decreased demand in developed markets for Canadian softwood might be offset (at least partially) by increased demand from new customers.

5) Increasing supplies of inexpensive, fast-grown lumber from softwood plantations are becoming an increasingly relevant source of competition for "traditional" sources of softwood.

2.4.2 Internal Environment

Many forest products companies are currently undertaking significant changes in corporate and competitive strategies. Corporate strategy can be thought of as the set of businesses within which a company chooses to compete. Competitive strategy can be thought of as the ways in which the company seeks to gain an advantage over rivals in its businesses.[6] There are a variety of ways to categorize corporate strategy. One broad discriminator is the degree of diversification undertaken by the company. A related discriminator is the nature of diversification. Economists tend to classify business linkages as horizontal, vertical or conglomerate. Horizontal linkages describe businesses that share product or geographic markets. Vertical linkages describe businesses that are stages of a common value-added activity. Conglomerate linkages describe businesses under a common ownership for which neither horizontal nor vertical linkages exist.

Students of business strategy have refined the economists' broad distinctions by recognizing that there are degrees of horizontal and vertical linkages. Moreover, there may be certain "core skills" that underlie a firm's advantages in specific markets, notwithstanding that those markets are not horizontally or vertically related in the economists' sense of those terms.[7] Hence, there is a broader scope for defining the nature and degree of linkages among business units outside the economics literature. Nevertheless, whatever the classification system, corporate strategy is

---

6 The seminal description of corporate and competitive strategies is found in Porter (1980).

7 It is beyond the scope of this report to detail all of the refinements to business strategy definitions of corporate strategy. For an early overview, see Rumelt (1974). An overview in the context of the forest products industry is provided in Booth and Vertinsky (1991).

ultimately concerned with whether the firm should increase the number of business activities it undertakes and, if so, how closely and in what ways the new businesses should be related to the existing businesses. The classification of competitive strategies has also undergone modification and extension since Porter's (1980) seminal contribution. Nevertheless, critical distinctions are primarily drawn between competing on the basis of a cost advantage (price leadership) or on the basis of product differentiation, on the one hand, and between focusing on specific market niches or across a broad range of markets, on the other.

While price leadership and product differentiation are not necessarily mutually exclusive strategies, Porter and others have argued that firms trying to compete along both dimensions simultaneously tend to be unsuccessful as an empirical matter. The issue of whether to focus on niche markets versus a broad set of markets is conditioned by, among other things, the magnitude of economies of specialization relative to the magnitude of economies of scope.

Booth and Vertinsky (1991) identify empirical linkages between proxies for corporate and competitive strategies and the financial performances of a sample of North American forest products companies. Their results support the following conclusions: (i) diversification across unrelated products and geographic diversification reduce risk, but at a significant cost in terms of financial performance, most notably rate of return; (ii) geographical diversification does provide opportunities for firms to grow when fibre supply constraints in the regions in which they operate constrain the potential for sales growth; (iii) product diversification into related markets is negatively related to growth of sales. Moreover, there is no evidence of economies of scope associated with related product diversification; (iv) both cost leadership and product differentiation strategies appear to be successful in increasing financial returns. Technological progress is increasingly the source of opportunities to reduce costs. Product differentiation requires either penetration of existing consumer markets (e.g. tissue and other paper-based consumer products) or the creation of market niches through product innovation; (v) in established consumer markets for differentiated products, barriers to entry are high, since incumbents are likely to defend their market niches by exploiting first-mover advantages related to past investments in advertising and R&D and a lower position on the learning curve.

It is a well-established observation that Canadian producers in both the wood products and pulp and paper segments of the industry tend to compete on the basis of price leadership (Cohen and Gaston, 1993; Roberts, 1993). That is, they tend to produce "commodity-type" products while emphasizing production efficiency. To date, this competitive strategy has been relatively successful, in part because of the access that Canadian producers have hitherto enjoyed to relatively low-cost, high quality fibre. To be sure, Canadian mills have also enjoyed good productivity performances, especially in the wood products sector; however, projections for rising stumpage prices for Northwest timber, decreasing relative costs of Southern Yellow Pine and increased environmental opposition to logging old growth forests are developments suggesting that it will be increasingly difficult for Canadian producers to successfully pursue a cost leadership strategy, all other things constant.

There are indications that Canadian wood products producers are beginning to embrace product differentiation strategies. For example, there has been some increase in the production of value-added products through recovery of clear and joinery quality fibre, as well as development of engineered lumber products (Cartwright, 1993). While competition in these areas can be expected, particularly from American and Asian producers, there is also expected to be rapid growth in demand for specialized wood products. This raises interesting issues about whether and how biotechnology developments in the forestry sector will affect the economics underlying different competitive strategies in the production of wood products and, further, whether the developments will favour certain sets of producers over others.

It is less easy to identify changes in competitive strategies on the part of Canadian pulp and newsprint producers. By and large, Canadian producers in these segments have been focusing on modernizing technology and improving the environmental standards of their mills (Cohen and Gaston, 1993). Moreover, they appear to be maintaining their cost competitiveness with other international producers, including U.S. and Scandinavian producers (Oum and Tretheway, 1989). However, the expanded use of recycled paper could markedly alter the economics of "conventional" pulp and paper production, along with Canada's position as a competitive low cost producer (Haynes and Adams, 1992).

Another development on the demand side of the markets for pulp and paper products with potentially important implications for Canada is the fragmentation of demand for paper products by, among other things, paper grade (Roberts, 1993). This development enhances the profitability of building mills that are dedicated to serving particular niche markets; i.e. competing through focused product differentiation. A number of European producers are apparently moving in this direction. Specifically, they are moving into higher value-added consumer-related areas such as hygiene and packaging products and away from an overriding dependence on lower value, cyclically volatile products such as pulp (Stanbury and Vertinsky, 1991).

European and Scandinavian producers are also apparently engaged in horizontal and vertical diversification in order to capture perceived economies of scale at the firm level and, in some cases, to reduce risk (Stanbury and Vertinsky, 1990; and Roberts, 1993). Conversely, Canadian forest products companies are getting smaller in relative size. Booth (1989) documents that firms producing a variety of pulp and paper products tend to be the least risky in terms of the volatility of their earnings; however, if shareholders can easily diversify in this segment through portfolio investments, it is unnecessary for management to diversify in order to achieve risk reduction. Moreover, it is relevant to note that firms with a consumer product focus such as tissue paper enjoyed higher overall returns than firms producing a variety of pulp and paper products (Booth, 1989).

2.5 Summary

In summary, economic developments affecting the forest products industry appear to be favouring competitive strategies emphasizing product differentiation with a focus on specific markets rather than cost leadership with a focus on a broad range of markets. This may be especially true for Canada to the extent that its traditional access to relatively low-priced high-quality fibre is eroded by the types of developments described above. Technological change can certainly help mitigate emerging cost disadvantages confronting Canadian mills; however, materials and labour costs have traditionally accounted for almost two-thirds of all costs in the pulp and paper industry (Oum and Tretheway, 1988). If access to these resources becomes relatively and significantly less favourable for Canadian producers, it is unclear that proprietary technological advantages can offset the associated disadvantages.

To be sure, it is also unclear what underlying advantages Canadian pulp and paper producers would have if they chose to compete primarily on the basis of a product differentiation strategy. Presumably, the brand name advantages enjoyed by long-standing producers of consumer-related products could be offset by introducing substantially improved new products. Moreover, the apparent trend of consumers away from buying branded products enhances the potential for entry into this product group. Brand name is unlikely to be as substantial a barrier to entry for new producers of industrial paper products. In both cases, however, one important critical success factor is likely to be harnessing technology to produce new and improved products. An evaluation of the implications of developments in biotechnology might usefully bear in mind the increasing importance of technology as a critical success factor in the pulp and paper segment of the industry. At the same time, it might also consider the possibility that biotechnology breakthroughs may have larger impacts on the "upstream" segment of the industry which, in turn, might mitigate (or accentuate) the apparently deteriorating competitive position of Canadian firms pursuing a cost-leadership strategy.

It is only possible at this stage to suggest the possible implications of breakthroughs in biotechnology research along the lines described in the relevant discussions. Taken as a whole, developments in seeds and biopesticides imply the potential for more rapid growth and better preservation of fibre stock. Given the importance of this underlying asset to Canada's performance in the sector, the potential is important. Moreover, Canadian firms (including non-profit organizations) will face a strong demand for the research - given Canada's large derived demand stemming from its large timber interests. In addition, biotechnology developments suggest the potential for modifying species to improve their "quality" as inputs to downstream activities. Again, depending upon the nature of the downstream activity, Canadian derived demand for this research could be quite important.

In short, while it can be argued that Canada is facing increasing competitive risks given the domestic forestry industry's focus on cost containment rather than higher value-added products, it is unclear that developments in biotechnology will accentuate those risks. Indeed, it is possible for biotechnology breakthroughs to enhance Canada's main underlying competitive advantage; i.e., ownership of high quality timber stands. Indeed, to the extent that major competitors in developed countries emphasize product differentiation strategies, a Canadian focus on improving "yield" and "quality" upstream might itself be an important distinguishing element of Canadian biotechnology strategies.

3.0 MARKETS FOR SEEDS AND BIOPESTICIDES

There are two major areas where biotechnology involving the creation of new multicellular organisms may have a significant impact on the forest products sector: (1) the production of seeds, and (2) the employment of biopesticides to protect the forest.

3.1 Seeds

Since the supply of improved seeds and seedlings is tightly integrated with the general supply of seeds and seedlings, we start this section with a description of the supply of seeds.

3.1.1 Sector Activity

In Canada, seed supply consists primarily of 8 species, as indicated in Table 14. The major sources of forest seed are listed below in order of decreasing seed quality. Table 15 indicates the proportion supplied from each source (note the small percentage of seeds source from orchards):

1) seed orchards (SO);
2) seed production areas (SPA);
3) seed collection areas (SCA);
4) controlled general collections; and
5) uncontrolled general collections.

Available data indicate a clear trend towards increased seed utilization in most provinces during the period between the late 1970s and the mid 1980s, as demonstrated in Table 16.

There were a total of 119 tree nurseries in 1984 in Canada, divided between public, private and forest industry sectors (Smyth and Brownwrite, 1986). The majority of nursery seedlings were destined for forest renewal projects on provincial crown lands. Of the 119 production centres, 43 reared bare-root stock and 101 reared containerized seedlings. The total stock available for planting was 206 and 252 million bare-root and containerized seedlings, respectively.

Tables 17 and 18 break down these statistics by province, separating bare root and containerized seeds. Table 19 breaks down seedling production by ownership. It is useful to highlight the relatively high provincial government ownership of seedling production.[8]

In terms of the overall trends in seedling production, in 1979, the total estimated number of bare-root seedlings shipped was 313.3 million. The number of containerized shipped seedlings was 178.2 million. This represents a mix of 65% bare-root to 35% containerized stock. In the following

---

8 There is a recent significant trend to privatize public nurseries in Canada.

5-year period, not only did the total number of seedlings increase, but the ratio of bare-root to containerized stock decreased. For example, by 1984, the ratio had changed to 55% containerized and 45% bare-root stock.

During the period 1979-1984, the most dramatic reductions in bare-root stock occurred in B.C. (20%), Saskatchewan (34%), and N.B. (30%). All provinces except Alberta and Saskatchewan increased the number of containerized seedlings shipped during the period. Quebec's output increased by 2685%, Ontario's by 695%, B.C.'s by 118% and N.B.'s by 23% (Smyth and Brownwrite, 1986).

It is interesting to note that the vast majority of harvested forest lands in Canada are largely left for natural regeneration. During the period 1977 to 1988, approximately 10.6 million ha were harvested. Of this, 25.5% was planted, 4.5% was directly seeded, and the remaining 70% was left to natural regeneration (Runyon, 1991).

3.1.2 Production of Seeds

Turning now to the process of tree improvement in more detail, we note that this process has predominantly involved classical genetic techniques, primarily through natural cone collection. The use of vegetative clones (grafting or rooting) is increasing, while somatic cloning is largely in the R&D phase.

Using British Columbia as an example, seed orchard activities are based on 24 seed planning zones representing varying geographic/ecological characteristics. Within each zone, future seed requirements are determined for each identified species. The majority of the seed orchards are cooperatives and come under the administration of either the Coastal or Interior Tree Improvement Council. Roughly half of these orchards are Crown facilities and half are private, with a strong trend toward the latter. From the seed orchards, the desired seed moves to the B.C. Seed Centre (Ministry of Forestry) for testing and/or storage, or is sold through any of a number of licensed dealers to nurseries from which seedlings are produced for reforestation. As of 1993, aside from the Seed Centre, the B.C. Ministry operated 3 nurseries, 9 orchards and contracted with 20 commercial nurseries to provide seedlings destined for Crown managed forest land.

Again using B.C. as an example, in 1979 a cooperative government/industry tree improvement program was created under the Tree Improvement Council, first for the Coast and then for the Interior in 1981. The objective of this cooperation was: (1) to establish programs to increase the levels of genetic gain through testing and breeding, and (2) to produce sufficient orchard seed, incorporating the highest available level of genetic improvement, to meet specific goals established for each species. These goals included the annual production of 40 million and 80 million genetically improved seeds for the Coast and Interior, respectively, by 1995. At present, however, the annual number of genetically improved seedlings planted in B.C. is roughly 25 million (roughly 10% of the total number of seedlings planted in B.C. annually compared to the goal of 60% in one year from now!). The B.C. Ministry of Forests' Seed Centre (the only place seeds are stored in the province), presently has 60,000 kilograms of seeds, representing 6000 individual registered seed lots, the bulk of which are wild stand seeds. The goal of the Seed Centre is to have 50% of its stock in storage genetically improved by the turn of the century. New legislation in B.C., however, **requires** that genetically improved seed must be used *where available*.

The rest of Canada utilizes similar cooperative tree improvement programs to that which exists in B.C. These cooperatives include the Nova Scotia Tree Improvement Group, the New Brunswick Tree Improvement Council, the Ontario Tree Improvement Council, and the Alberta Cooperative Tree Improvement Program (Quebec announced in 1987 the tentative formation of a tree improvement cooperative).

In the United States, a total of 2,544,862 acres were planted in 1992 (acres planted in the U.S. have ranged from roughly 1.5 million to 3 million per year since 1960) (USDA Forest Service, 1994). Of these, the forest industry planted 1,098,886 acres (43%), nonindustrial private forest landowners 1,028,728 acres (40%), and the balance was planted by the National Forest service and other public institutions (17%). When broken down by region, 70.4% of this planting was done in the South, 23.6% in the West and 6% in the North.

In terms of nursery production, 1992 saw 1,598,800,000 seedlings shipped. Of these, 47% came from forest industry-owned nurseries, 29% from state owned nurseries, 15% from other industry sources, and the balance (9%) primarily from federal nurseries. The majority of this nursery production is in the South (68.4%), followed by the West (21.5%) and the North (10.1%).

It should be noted that the federal orchards and nurseries exist exclusively to supply seedlings for planting on federal forest lands (i.e. they do not sell to industry). The state owned orchards and nurseries, on the other hand, sell almost exclusively to the private sector, mostly to non-commercial forest owners. Private orchards and nurseries exist not only as backward integration for forest companies, but also to sell excess seedlings for restocking federal lands.

The U.S. has a number of federal assistance programs for forestry (administered by the USDA), which are (not unlike FRDA) largely used for reforestation. There are four programs in total, which in 1992 involved funding for the planting of 435,898 acres. These are: (1) the Forest Incentives Program (responsible for 37% of the acreage planted through assistance); (2) the Agricultural Conservation Program (27%), (3) the Stewardship Incentive Program (1%), and (4) the Conservation Reserve Program (35%). The largest of these, however, might be terminated in 1995. Specifically, under the terms of the 1990 Farm Bill, the Forestry Incentives Program is subject to Congressional approval in the 1995 Farm Bill.

The situation in the United States regarding seed improvement is more varied than in Canada. In the Pacific Northwest, for example, the situation is similar to that of B.C. The OECD statistics from this region indicate that of the roughly 4500 kilograms of seed currently exported, only 5% originate from genetically improved stock from seed orchards. However, taking the U.S. South as the opposite extreme, an estimated 95% of seed exports are genetically improved, most of which is destined for China. This is only an estimate as these sales are not registered through the OECD (as China is not a member). The U.S. North lies somewhere in between, with approximately 50% being genetically improved seeds.

3.1.3 Demand for Seeds and Improved Seeds

3.1.3.1 The Factors Influencing Demand

The demand for seeds and seedlings is derived from reforestation decisions. In Canada governments own about 95% of commercial forest lands and thus control the amount of trees planted. Generally, harvesting is done by private companies which pay stumpage to the Crown. The tenure arrangements vary between provinces, and some provinces have lands under different tenure systems. In all cases the government is either responsible for reforestation of harvested stands or requires companies to plant the harvested stands. The government may prescribe specifically what types of seeds are to be used to replant its lands or, as is the case with the Tree Farm Licences of B.C., impose a requirement that harvested stands will be replaced with trees in a "free to grow" stage of development within a specified period. A specific regulation may consider the value of the tree to the owner (the government) when it matures and thus provide incentives to demand certain types of improvements. A more discretionary regulation, such as the "free to grow" stipulation, imparts a different set of incentives in the decision to use improved seeds and the kinds of improvements to "buy". A company without long term security of tenure may opt for improvements that reduce the costs of achieving a stand in a free to grow stage, but it will not be particularly willing to invest in improvements when the benefits may not accrue to it. In this regard, even if the company has secure access to the harvests of the improved trees, it is possible that higher stumpage will be imposed by the province to reflect the higher quality of the trees. Not surprisingly, Canadian forest product companies operating on public lands have interest in short term, "insurance" type improvements (i.e. those improvements which protect forests in the short run and thus protect harvesting rights). This bias is especially strong if the costs of protection themselves accrue to the forest products company. If costs of reforestation are borne by the government, private companies may have incentives not only to acquire improved seeds that protect the stock but also to pay for improvements that will increase growth rates and quality. While the willingness to pay for such improvements may be low, the improvements have option values for the forest company, as long as the company has a chance to enjoy part of the benefits that the improvements will produce.

Private land owners (who predominate in the U.S.) are more likely to demand improved seeds. The timing of anticipated benefits and the uncertainties associated with the realization of benefits are important factors in private forest owners' decisions. Thus, the shorter the rotation period, the stronger will be the incentive to buy improved seeds. "Insurance" and growth oriented improvements that protect and enhance the value of the stock throughout the rotation are likely to be more attractive than quality improvements, *ceteris paribus*, since future markets for the latter are more uncertain than those for the former.

3.1.3.2 Data on Demand for Seeds

To give a sense of the dollar value of the domestic demand in Canada, Table 20 shows the total expenditures for site preparation and regeneration for 1991, broken down by source of funding. To give an indication how these levels translate to dollars spent on trees, utilizing B.C. as an example, in 1991 there were 213.1 million trees planted at a cost for trees alone of $35.8 million (or approximately 17 cents per tree). Figure 2 shows the total number of seedlings, planted from 1975 to 1989, both by stock type and by region.

Unlike seedlings, there is a fairly active trade in seeds, especially exports from Canada and the U.S to Europe and Asia (as well as a limited amount of trade from the Pacific Northwest to B.C. for Douglas Fir), which allows us to get a sense of the international demand. Unfortunately, there is a limited amount of data on trade in tree seeds. One of the only sources that exists is the Organization for Economic Cooperation and Development (OECD), which certifies seed trade among member companies.

Tables 21 and 22 give an indication of the amount and value of seeds certified in Canada and B.C. for export. These exports included 11 species, with Douglas fir, Sitka spruce and to a lesser extent Lodgepole pine making up the bulk of trade.

In the U.S., while there are some exports of seeds from the Pacific Northwest (as already mentioned in an earlier section), the largest exporter over the past decade has been the U.S. South. Exports from this area, primarily to China, have reportedly been in the range of 50,000 to 100,000 kilograms per year, primarily in Loblolly and Slash pines (Karrfalt, 1994). However, as China begins to collect its own seeds from grown stock, this market will diminish.

As we have indicated above, the main source of seeds and seedlings used by the large companies in the U.S. are derived from their own seed orchards and nurseries. Most companies engage in some breeding activities, mostly using traditional genetic selection methods. Smaller companies obtain their seed and seedlings from state run nurseries or cooperatives. These also seek to improve their seed. Among the large forest products companies, Weyerhaeuser and Wesvaco are the most active in the development of improved seed using "new" biotechnology. Some improved seeds are sold by Wesvaco to other companies. These sales are done through contracts designed to keep the IP rights with the seed producer. Generally, the quantity of armslength sales of somatic seed is very small at present.

3.2 Biopesticides

There is a well developed market for biopesticides for forestry applications. The market is highly concentrated. The major class of biopesticide which is used is based on B.t. and the four largest companies supplying the market account for 92% of the global production of B.t. products: Abbott 45%, Sandoz 25%, Novo 10% and Duphar 12% (Agrow Consulting, 1993). The remaining 8% is split between roughly a dozen additional companies (Agrow, 1993).

3.2.1 Sector Activity

Abbott (a U.S. company) holds the largest share of the biopesticide market and at one point controlled 75% of all biopesticide sales (agriculture, forestry and human health). Today, it holds a 60% market share of forestry biopesticides. Sandoz (a U.S. company), on the other hand, concentrates more on biopesticides for the vegetable industry. Novo (a U.S. company) has a significant involvement with forestry biopesticides, including sales to the U.S. Forest Service for control of Spruce budworm and gypsy moth. Further, Novo established a subsidiary, Entotech, in Davis, California in 1990 to undertake biopesticide R&D for both agriculture and forestry applications. Duphar (a Dutch company) is a subsidiary of Solvay (see below) that is primarily involved in crop protection.

Private sector producers can be divided into several strategic groups (Agrow Consulting, 1993):

1) Large multinationals that have spare fermentation facilities. Abbott and Novo are both good examples of this group. Both have extensive fermentation capacity from their pharmaceutical production. On a smaller scale, the pharmaceutical multinational Solvay, through its Dutch subsidiary Duphar, also produces B.t. products in a similar manner. There are also cases where one chemical company contracts with another to provide B.t. products; Pfizer has such arrangement with Ecogen, where Pfizer ferments Ecogen's product (including *Condor*, a biopesticide used in forestry applications).

2) New biotechnology companies. The approach of these companies is to specialize in biotechnology products (as opposed to attempting to realize economies to scale through co-production that uses excess fermentation capacity). Typically, such companies own the right to a new strain or own the rights to a unique process (e.g. a process which increases the potency of a toxin or improves application qualities). Mycogen and Ecogen are the most significant companies in this group. Both hold a number of patents on new strains and formulation processes.

3) Large agrochemical companies. Dominant examples are Monsanto, Shell, Du Pont, Ciba-Geigy and BASF. Of interest here is that most of these companies do research in genetic engineering of agricultural plant tissue for purposes of increased yield and better adaptation to environmental factors. This provides the group with a comparative advantage in R&D involving the incorporation of B.t. toxin genes in selected agricultural crops.

A full list of companies involved in the commercial production and marketing of B.t. products is shown in Table 23. Also included is an indicator of the sophistication of the products. While most of the columns describing the technology of the B.t. product are self-explanatory, one technology ("microbe-mediated delivery") requires some additional comment. This technology was developed as a solution to past constraints on the application of B.t. that stemmed from inadequate delivery to the target and limited residual toxicity (thus requiring multiple applications). With micro-mediated delivery, the B.t. toxins are inserted into microorganisms that are associated with the target insect habitat. The transformed organism colonizes and continues to synthesis the

B.t. toxin, thereby reducing or eliminating the need for further applications. Although not shown on the table, another way to accomplish this goal is through *transgenic plants*, where the B.t. toxin gene is incorporated into the commercially valuable plant itself.

There are no significant Canadian firms in the biopesticide market.

3.2.2 Demand for Biopesticides

The determinants of the demand for biopesticides are comparatively straightforward. They involve consideration of costs, effectiveness and regulatory requirements. Generally intensive uses of pesticides in forestry are triggered by large infestations and are mandated and paid for by governments (both in Canada and the U.S.).

From 1983 to 1991, it is estimated that forest insect pests were responsible for an average loss in Canada of 800,000 hectares per year. This is 3 to 4 times the size of the entire B.C. harvest. Estimates of losses in sustainable harvest levels in Canada due to the Spruce budworm alone range from 33% (Deloitte & Touche Management Consultants, 1992), 50% (Arif, 1994), and 70% of total insect damage (Canadian Forest Service, 1991). Losses from diseases add to the value. The Canadian Forest Service, for example, estimates total annual mortality (insects and disease) for Canada at 62.3 million m^3 over 1982-1986. Of this, 16.1 million m^3 is attributed to diseases (or 26%).

Potential market demand estimates for forest bioherbicides alone are $9 million per year for Canada and $76.5 million per year globally (Canadian Forest Service, 1994).

Unlike the application of biotechnology to conifer seeds, the incentive to create and improve biopesticides for forestry applications has been strong. In fact, in spite of forestry representing a very small percentage of total pesticide use, including chemicals (in Canada, roughly 2% as compared to 93% for agriculture), the forest industry has been a driving force behind the development of biopesticides.

As already described, by far the most successful biopesticide today is B.t. Although it has a history dating back to the turn of the century, it has only been in the last ten to fifteen years that B.t. has become a commercial success. The development of recombinant DNA technology in the 1980s, coupled with growing environmental pressures to reduce the reliance on chemical pesticide applications, propelled research and commercial interest to the point of overcoming many of the earlier shortcomings of biopesticides. B.t. was singled out for its past success, relatively low development costs, large number of strains (high natural diversity) and good prospects for genetic manipulation (van Frankenhuyzen, 1993).

The reason that the forest industry played such an important role in the development and ultimate success of B.t. stems largely from the disadvantages commonly associated with biopesticides as compared to chemical pesticides. As noted in Section 2, microbial insecticides tend to be highly target specific, limiting single applications to a single pest. While this is not well suited for agriculture, it is appropriate for most forest applications (e.g. targeting the Spruce budworm). Agricultural applications of pesticides strive for virtually 100% eradication since agriculture is typified by highly intensive production and slightly damaged fruits and vegetables loose a significant proportion of their market value. Forest applications, on the other hand, are often satisfied by eradication levels of 30-40% By the end of the 1970s, "performance of B.t. for Spruce budworm control had improved to the point that it was considered an operational (but still more expensive) alternative to chemical insecticides" (van Frankenhuyzen, 1993, p. 3). In the decade that followed, many of the cost disadvantages were eliminated, making B.t. a highly competitive product.

Another reason for B.t.'s success in forestry as compared to agriculture is that forest lands have tended to be under greater public scrutiny by environmentalists and regulators. In most of Canada, B.t. is now the only insecticide allowed for aerial spraying of forests. The economics of the use of pesticides generally and chemical pesticides in particular was a target of recent research. Pimentel, *et al.* (1992), in a recent study on the environmental and economic costs of pesticide use in the U.S. concluded that an annual investment of $4 billion dollars in pesticides saves roughly $16 billion in U.S. crops and fibre (based on direct costs and benefits only). They estimate, however, that the indirect environmental and public health costs exceed $8 billion. In contrast, a recent study which assessed the net value of B.t. in the control of Spruce budworm in Eastern Canada found that for every dollar invested in spray control, over $5 was generated as a net return. In addition, it was shown that a 1% increase in timber value increases the net return by roughly $1 (Deloitte & Touche Management Consultants, 1992). These are net gains, since the use of biopesticides does not involve significant environmental costs.

The development of biopesticides is cheaper than the development of comparable chemical pesticides. The cost of producing synthetic pesticides has escalated dramatically. Today, it is estimated that it takes 7-10 years and $15-30 million to develop a chemical pesticide, compared to only 2-3 years and $1-2 million for biopesticides, with most of the savings being in the registration process. Our interviews indicated, for example, that registering a biopesticide in Canada takes a minimum of four years, with the added stipulation that the time requirement can be doubled if a company is starting from scratch (i.e. 4 years assumes that the research trials have already been performed and that documented data can be given to the regulators). The cost of this process is estimated to be $6 million. The registration costs in the U.S. would be even higher but note that the registration process confers some protection of IP, since the possession of the research data required for registration remains proprietary).

The regulatory uncertainties with respect to the use of chemical pesticides is high. Indeed, it was reported that over one quarter of all currently registered pesticides are in immediate danger of being withdrawn (Agrow Consulting, 1993). Evidence was also reported that insects are developing resistance to chemical pesticides, a problem not encountered so far with biological control. An "unofficial" goal of the United States is to replace 50% of all chemical pesticides (including those in agriculture) with biopesticides by the year 2000 (Dorworth, 1994).

3.2.2.1 Data on the Demand for Biopesticides

By the end of the 1980s, global sales of B.t. were estimated to be roughly $50 million. The sales constituted less than 1% of the total insecticide market worldwide; 60% of these sales were for North American forestry applications (van Frankenhuyzen, 1993). One decade later world sales were estimated to be $105 million[9]. The sectoral mix changed to 60% agricultural applications (Agrow Consulting, 1993), 20% related to human health, and the remaining 20% in forestry applications (again, mostly North America) (van Frankenhuyzen, 1993). Other estimates suggest that B.t. use in forestry is as high as 35% of the total global usage. It should be noted that these figures compare with an estimated market size of $20 billion for global agrochemical sales, of which roughly 25% represent product sales for insect control.

Agrow Consulting (1993), in a comprehensive report on biopesticides, projected over $270 million sales of B.t. pesticides by the year 2000. Clearly some of the demand for biopesticides will shift from the bacteria as the delivery mechanism to other means of toxin delivery (e.g. viruses). Transgenic trees in which B.t. genes have been incorporated are now available, but they are not likely to pose a commercial threat to the direct application of biopesticides for at least two decades.

[9] North America, 57.2 million; Far East, 13.6 million; China, 10.4 million; Central and S. America, 8.1 million; Middle East and N. Africa, 5.1 million; rest of Africa, 7.8 million; Australasia, 2.1 million; Western Europe, 0.7 million.

4.0 BIOTECHNOLOGY IN THE FOREST PRODUCTS SECTOR: STATE OF THE ART, RESEARCH TRENDS AND THE COMMERCIAL POTENTIAL

Biotechnology encompasses both centuries-old techniques such as plant and animal improvement through selective breeding and new techniques such as industrial use of DNA and cell fusion. "The traditional methods of gene transfer have been used for thousands of years to alter animals, plants and microbes to serve human purposes. To many interested parties, the new techniques involve no radical departure from historical practices. Instead they enable plants and animal breeders to accomplish the same goals more quickly, easily and surely" (Kostenmeier, 1989, p. 441). The "new" biotechnology has its scientific roots in the discovery of the replication process of rDNA by Francis Crick and James Watson about forty years ago (Crick and Watson, 1954); however, the commercialization of biotechnology both in terms of research and the development of new products and services is less than twenty years old. The areas of application reflect both economic factors and the ease of the applications themselves. In this regard, the relative difficulty of altering trees (compared to many annual plants) and the long horizons involved in receiving payoff from investments in tree improvement have meant that the task has received relatively little attention and funding to date. The growing pressures on forest land to meet demands, and the shrinking land base of the forest, are likely to stimulate scientific and commercial interest in forest related biotechnological research and development.

There are three broad areas of application of biotechnology in the forest products sector. They include: (a) tree improvement, (b) control of pests, (c) improvement of industrial production processes and bioremediation. These areas are not mutually exclusive. Thus, for example, some activities to improve trees involve enhancement of the ability to resist diseases or insects. Other attempts to improve trees have the objective of producing fibre characteristics which enhance industrial conversion processes.

4.1 Tree Improvement

In contrast to many agricultural crops the history of selection and improvement of forest tree species is rather short (the largest systematic breeding program consists so far of four generations in one of the eucalyptus species and three generations in some pine species). The classical genetic techniques rely on the broad natural variability of genotypes within populations. Selections have traditionally been made for superior yield and form, although protection or "insurance" characteristics (such as insect and disease resistance) have also been used as criteria. More recently, some breeders have begun to include wood quality characteristics (Trotter, 1990). Haines (1994) observed that "significant genetic gains are being achieved but, in particular for the long rotation species, there has been only a minor impact to date on the genetic quality of populations" (p. xii).

The major constraints that limit classical tree improvement methods are associated with (1) the time involved (long inter-generational intervals); (2) the relative lack of knowledge of the relationships between the genetic structures of trees and tree characteristics over time; and (3) the difficulties in controlling the selection process in open-pollinated seed orchards. Most forest planting stock is still derived from genetically undefined seed origins. "This has arisen chiefly because of the long juvenile period and the length of time required to investigate fully the performance of promising selections derived from crosses" (Hammatt, 1992, p. 370). The option of observing characteristics in the early stages of tree growth to predict the characteristics of mature trees and thus save time is not viable. This is so because there are poor or even negative correlations between the characteristics of juvenile and mature trees (Namkoong and Kong, 1990).

Breeding can be performed without understanding the precise relationships between the genetic make-up of the tree and the desired characteristics bred for, but more efficient breeding will be possible with an increase in the fundamental knowledge of the genetic regulation of the desired characteristics of a tree. Time is thus a major constraint in the progress of tree improvement programs. Cheliak and Rogers (1990) identified four ways in which time influences tree improvement processes. They are (1) evolutionary time, (2) time to harvest, (3) time to achieve phenotypic stability, and (4) time to reach reproductive maturity. Biotechnology offers novel approaches to the time problem. The approaches include: tissue culture and embryogenesis, molecular genetics and genetic engineering.

Somatic embryogenesis is a tissue culture method for asexual propagation. It shortens the time needed for placing superior stock in the field. It offers an excellent vehicle for "massing up" superior families without the risk of losing or diluting desirable traits. Further, it allows the maintenance of individuals in a juvenile state capable of regeneration for ten or more years for testing and selection in the breeding process (root cuttings for multiplication of clones are limited in this regard). As a result of these characteristics of propagation using tissue cultures and embryogenesis, one can shorten the time for achieving phenotypic stability and for developing and maintaining preferred traits.

Molecular genetic approaches have important applications in advanced breeding programs in relation to quality control (e.g. checking clonal identification, orchard contamination and within orchard mating patterns by "finger printing"). Genetic markers can also be useful for the quantification of genetic variation to aid in sampling strategies for gene conservation and breeding population collections. "Realistically, application of marker-assisted selection in the short and medium terms is likely to be very limited. Cheaper markers would be required and, even if these were available, the technology would apply mainly to advanced breeding programmes where the creation and maintenance of the appropriate population structure could be afforded, and where clonal forestry is achievable" (Haines, 1994, p. xvi).

The major value of markers is, however, in their use in research to understand the basic genetic mechanisms. "Tree breeding programs based on selection of traits require long term investment and several generations of selects before major improvements are seen. Furthermore, in following a program of selection of traits, we presuppose that they exist in the tree's genetic make up" (Trotter, 1990, p. 199). Some tree improvement strategies focus not on enhancing quantitatively pre-existing traits but seek to introduce to the tree traits that did not exist naturally. Recombinant DNA techniques make it possible to transfer specific genes into the host plant to create a new genotype. Crops transformed with genes for insect and virus resistance and resistance to various types of herbicides are at or near commercial application. Successful examples which are available now include insect resistant poplars. It should be noted, however, that research focused on poplars not because of their value in industrial forests, but because of the relative ease of their transformation.

Manipulation which involves several genes is less likely in the near future. The R&D strategies of the U.S. Forest Service, for example, place a great emphasis on gene mapping. It is argued that better understanding of genetic controls of traits will permit superior targeting of gene transfers to achieve traits that involve more than one gene.

An important aspect of prospective commercialization of genetically engineered (transgenic) trees is the cost and duration of field testing. Testing could be extensive and lengthy depending on how complete our knowledge is of the genetic structure of the improved tree, the genes that are involved and the length of time till maturation.

Haines (1994) assesses the mid and short term commercial potential of alternative tree improvements targets. He suggests that insect resistance is of potential value, especially in the poplars, some pines, eucalyptus and tropical hardwoods. A single gene transfer is often involved in establishing resistance to specific insects when short rotations are involved. When long rotations are involved, it is necessary to introduce several resistance genes to reduce the chance that the insect will evolve and acquire tolerance to the toxics produced by the tree. This is a much more complex and time consuming task.

Another line of research that is being pursued, and which is likely to result in commercialization within a decade, is modification of lignin biosynthesis through antisense technology. The reduction of lignin biosynthesis may reduce significantly costs of pulp production as well as the use of chemicals and energy (thus providing a potential for product differentiation through an emphasis on its "green" qualities). The potential value to the industry has attracted funding to support research on pulp tree quality improvement.

Introduction of herbicide tolerance is feasible, but its potential value in allowing the use of unguarded herbicide is not likely to exceed the costs of such trait development; however, the value of herbicide resistance may rise if it permits the use of more environmentally friendly herbicides than are used now.

Cold tolerance genes are likely to be valuable in introducing species across geographical zones. The research strategy is not certain at the moment, since it is not known whether using antifreeze proteins can confer sufficient tolerance to cold.

One important concern in the application of genetic engineering to trees is the prevention of gene escapes into wild populations. This can be achieved by inducing tree sterility (sterility may also enhance growth as the tree will reduce the energy spent on reproduction).

"The major factor limiting application of genetic engineering in forest species is the state of knowledge of molecular control of the traits which are of most interest - those relating to growth, adaptation and stem and wood quality. Genetic engineering of these traits remains a distant prospect" (Haines, 1994, p. xviii).

To conclude, tree improvement is more difficult, costly and uncertain compared to the improvement of many agricultural crops. The long rotations, and thus the long breeding and testing processes which are required for commercial application, reduce the present value of the expected benefits. Similarly, the high uncertainties involved in the research and development process reduce the risk-adjusted expected payoff. There are also geographical constraints on the use of improved seeds although the tolerance zones vary by species and the type of improvement. Many of the improvements involve a combination of classical breeding with biotechnology, where biotechnology allows more efficient and less time consuming breeding, and also enhances propagation once an improved stock is developed. This means that one must consider in an analysis of IP protection the complex relationships between potential claims of breeders for the original improved stock, the rights for further improvements using, for example, culture tissue technologies, and the rights to the processes for generating viable somatic seeds.

4.2 Control of Pests

One strategy of pest control which is receiving increased attention is the application of biopesticides. The strategy consists of the application of living agents or their metabolites to reduce a target insect population, either in numbers, vigour or both. "A variety of herbivorous and parasitic insects and mites, as well as herbivorous mammals, microorganisms and even fish (for control of aquatic weeds) have been employed in interactional or integrated pest management efforts" (Dorworth, 1992, p. 2). Most biocontrol organisms in use produce toxins that kill pests, reduce the potency of the pests or prey on the pests. In the forest sector, the bacterium *Bacillus thuringiensis* (B.t.) has been the organism most commonly used to control large infestations. For example in 1990, 60% of all budworm and gypsy moth control programmes in North America were conducted with B.t. (van Frankenhuyzen, 1993). Intensive use was also reported in other regions of the world (e.g., Weiser, 1986). The major constraints on the use of B.t. (and other microorganisms) is the narrow spectrum of insecticidal activity. While a high degree of specificity is good for the environment, the use of these biopesticides is sometimes not effective. This is largely the case in agriculture where one must control multiple pests. In fighting forest epidemic infestation, however, specificity is a desirable attribute, especially when the protection of other organisms is desired. Another problem encountered in the use of pesticides based on naturally occurring B.t. is their low residual toxicity (B.t. is washed out by rain). Sunlight also tends to inactivate the spore and toxins of the bacteria. Biotechnology is instrumental in identifying, selecting and improving bacteria to reduce these limitations and improve performance of the pesticide to satisfy the objectives of particular control programmes.

The emergence of rDNA technology and other genetic techniques was an important stepping stone in allowing registration and patenting of these organisms. Biotechnology was instrumental not only in identifying and selecting bacteria but also in enhancing and changing their characteristics through genetic engineering. Current technological advances, however, are outstripping the ecological knowledge that is required for the development of more potent biopesticides in the environment, especially the introduction of engineered organisms. Use of naturally occurring bacteria or dead bacteria (which are used as a non-living delivery system) are at the moment the preferred methods of bio-pest control.

In the future, once environmental concerns can be more adequately addressed, improved biopesticides are likely to assume a more important role not only in forestry but also in agriculture. Genetic engineering is likely to expand the range of microorganisms that can be used as delivery systems for biotoxins. Great interest is now shown by researchers in the introduction of viruses as means of delivering toxins to insects. The use of larger organisms as predators to control insect population is also being experimented with. The use of multicellular organisms for this purpose, however, is limited by both economic and ecological concerns. While bacteria can be multiplied using relatively simple and cheap fermentation equipment, many natural predators (e.g. nematodes) which prey on other pests are more difficult and expensive to raise and typically require a longer duration to produce a significant impact on the pest population. Better understanding of the forest ecology may offer more opportunities for the use of both natural and transgenic multicellular organisms as pest control mechanisms. Research now focuses (both with micro and other organisms) on the ability to create a live delivery system of toxins that can be switched off and on by using enhancers or suppressors external to the organisms. This may create a permanent system of pest control with lower environmental risks. Switch-off mechanisms can also prevent the adaptation of insects to biopesticides, thus maintaining their effectiveness for longer time periods.

4.3 Improved Production Processes

Most of the applications of biotechnology to improve production processes are in the pulp and paper industry. Much of the interest in biotechnology in this industry stems from environmental and health concerns. However, some of the processes developed also provide other benefits such as energy savings.

Biological bleaching of kraft pulps is a new but perhaps the most promising application of biotechnology in pulp manufacturing. Direct bleaching with fungi requires no chemicals, other than nutrients. A pre-bleaching fungal process is not yet ready for commercialization, but xylanase pre-bleaching seems to be. Deracination of wood chips and pulp is another process that has been developed and applied experimentally. Other biotechnologies in various stages of the R&D process include the following (Bourbonnais *et al.*, 1991): (i) biomechanical pulping: pretreatment of wood chips for mechanical pulp with various fungi has been shown in the laboratory to reduce refining energy and improve strength; (ii) liginase and biomimetic pulping: the discovery of lignin-peroxidase (liginase) in 1983 led to hopes that the enzyme would be applied in pulping and bleaching. The original reports claimed that the enzyme was capable of depolymerizing certain lignins. Results of pulping and bleaching experiments have been disappointing; (iii) wood protection during chip storage: this potential application remains an open opportunity. A fungus was identified as being capable of protecting wood against rot in laboratory tests, but a satisfactory method of using this fungus has not yet been developed; (iv) control of slime in pulp and paper operations; (v) glucose via enzymic hydrolysis of primary clarifier sludge; (vi) colour removal from pulp bleaching effluent: since 1984, the interest in treating bleachery effluents has escalated, but not for colour removal. Instead, the main interest is in the removal of toxicity resulting in part from the presence of chlorinated organics.

Biotechnology is likely to offer solutions to many health and environmental problems associated with the production of pulp and paper. In the long run the combination of tree improvement and bioprocessing is likely to give rise to new types of products. However, much of the development will be induced by regulation. All of the forecasted applications of biotechnology for bioprocessing anticipate the use and modification of microorganisms (no multicellular organisms are likely to be involved in the foreseeable future).

4.4 General Description of the Biotechnology Sector

In this subsection we address the general evolution of commercial activity in biotechnology and describe the market structures in some of the key countries where significant biotechnological R&D activity takes place. We conclude the section with a discussion of the supply of biotechnological products in the three key market segments that affect the forest products sector: (a) the supply of somatic tree seeds, (b) the supply of biopesticides, and (c) the supply of bioprocessing technologies for the pulp and paper industry.

4.4.1 Overview of Activity

Biotechnology was initially developed in the United States, funded mainly through government support for basic biomedical research. Not surprisingly, the first firms to exploit these new techniques were dedicated biotechnology companies focusing on diagnostics and therapeutics. Later, the scope of applications expanded with the development and commercialization of biopesticides. Other areas of application are now emerging rapidly, but few commercial enterprises in these new areas have shown profit.[10]

Applications of biotechnology largely compete with existing products. Some established multinational firms in sectors where biotechnology offers alternative processes or substitute products have invested in biotechnology, often as a defensive measure. More recently, encouraged by market demand, some multinationals have increased their commitments to the development of new product lines. Some have developed in-house biotechnology research capabilities, while others have acquired these capabilities through linkages with small firms; e.g. through mergers,

---

[10] The global market for biotechnology in 1993 is estimated at US$36 billion of which the biopharmaceutical portion is around $7.7 billion. Industrial enzymes (food detergents, diagnostics, fine chemicals, etc.) account for another $900 million, bioremediation for $400-500 million, and veterinary vaccines for $1,060 million. This estimate probably includes considerable traditional biotechnology product sales in addition to rDNA based products. Agbiotech products in the form of transgenic seeds, plants and produce are just beginning to enter the marketplace and are expected to penetrate rapidly over the next ten years. See James G. Heller Consulting Inc. (1994).

acquisitions and other forms of alliances. Some large companies (e.g. forest products companies) have developed in-house research capabilities when biotechnology offered them advantages in their traditional business (e.g. tree breeding). As the scope of application in biotechnology has expanded, and with the entry of the multinationals to the market, the smaller dedicated companies have tended to narrow their focus of R&D.

4.4.1.1 The United States

In 1988 there were 296 dedicated biotechnology companies in the U.S. and 53 large diversified companies with biotechnological divisions. Only 8% of the dedicated companies focused on improving plants (13% of the large diversified companies). Most of the sector is still focused on medical and pharmaceutical products, and to a lesser extent biopesticides, given prospects of greater market rewards in these areas of application (OTA, 1991).[11] Government and other publicly funded institutions continue to be the main players in biotechnology applications outside these fields.

A significant part of the federal funding for research is directed to university scientists and government laboratories. Several agencies are involved in biotechnology. The National Institute of Health (NIH) has played the most important role in stimulating the growth of biotechnology in the U.S. In fiscal year 1990 it provided about $2.9 billion in biotechnology-related research grants and contracts. It also contributed substantial funds to industry research through its Small Business Innovation Research Program. The program supports research collaboration between NIH scientists and biotechnology companies. Its major focus is on medical applications where its contribution to basic biotechnological research is dominant and creates significant externalities for other application areas. The National Science Foundation provided $168 million in 1990 to universities for biotechnological research in all fields, including forestry applications. The USDA's 1990 funding for research in biotechnology was $116 million. Within this budget, the Forest Service was allocated $3.6 million for research in forestry related biotechnology. Ninety percent of this budget was spent in Forest Service laboratories. Other federal departments made much more modest contributions to biotechnology R&D.

4.4.1.2 Canada

International interest in biotechnology has grown significantly in the past decade. Though the U.S. continues to dominate innovative activities, significant capabilities have been developed in Japan and Europe. Canada is a relatively minor but significant player in the field of biotechnology. Over 200 commercial firms were involved in biotechnology in 1990 in Canada (OTA, 1990). Most of these companies were small (less than 5 employees and $1.5 million in sales). Only about 30 companies were fully involved with modern biotechnological techniques, and only one company had more than 100 employees. The federal government is a major player in biotechnology, though

[11] The United States is estimated to hold some 40% of the biopharmaceutical market. (Heller Consulting Inc. 1994, p. x).

federal funding for biotechnology R&D is relatively small (Cdn $157 million in fiscal year 1988-1989).[12] Universities and federal research establishments claimed most of the federal funds. Research in universities provided the main stimulus to the emergence of several R&D companies, providing trained professionals and rights to some processes and products developed as part of publicly funded research programs.

A review of Canadian patent database statistics reveals a significant decline in Canadian biotechnology patent applications since the peak of around 2,350 applications in 1989. The U.S. is the largest source country for biotechnology patent applications filed in Canada (49%), followed by Japan (13%), Germany (8%), U.K. (6%), France (5%), Switzerland (4%) and Canada (3%). In terms of priority filing, i.e., the country of first filing of a patent application, Canada had only two filings (Heller Consulting Inc., 1994).

4.4.1.3 Germany

Germany is the most important biotechnology centre in Europe. The majority of biotechnology activities are concentrated in large firms. Some of the firms (e.g., Bayer and Hoechst) are funding R&D in biotechnology at rates reaching $100 million a year. Several of the large firms have gained access to U.S. technologies through acquisitions (e.g. BASF $1 billion acquisition of Inmont) (OTA, 1991). The federal government in Germany is also a major player in the biotechnology field, but its efforts are largely focused on basic research. Its main thrust has been through the National Research Centre for Biotechnology, established in 1976. It also provides funding for university research centres as well as independent public institutes. The government's national biotechnology program has been instrumental in increasing the pool of R&D professionals through the support of young scientists. State governments are also involved in funding research within their boundaries.

4.4.1.4 United Kingdom

In 1990 there were 300 British firms involved in biotechnology, although only about 40 companies were involved in genetic engineering. Large firms dominate the industry though the U.K. "boasts more small innovative firms than any other European country" (OTA, 1991, p. 242). Government direct spending on all biotechnology in FY 1987-1988 was approximately $130 million. In contrast to most countries with a significant biotechnology sector, the U.K. government does not play a leadership role in the industry.

---

[12] Canadian government spending for biotechnology was estimated at $160 million in 1991-92. Aggregate Canadian R&D expenditures for biotechnology totalled $991 million in 1993. (See Heller Consulting Inc. p. xiii).

4.4.1.5 Japan

In Japan the private sector leads investment and research in biotechnology, in contrast to the U.S. and Canada where government and universities "represent the driving forces behind the advancement in biotechnology, and basic research claims a large share of public R&D funds" (OTA, 1991, p. 243). The Japanese government funds approximately 20% of biotechnology-related R&D. The government, or more specifically the Ministry of International Trade and Industry (MITI), has sponsored two important research collaboration programs: (1) The Japan Bioindustry Association with participation of 320 companies from diverse industrial areas, and (2) the Research Association for Biotechnology which includes large Japanese firms (e.g. Mitsui and Mitsubishi chemicals).

In 1990, about 300 Japanese companies reported some type of R&D activity related to biotechnology. Large traditional firms are dominant in the commercial sector. Estimates for 1987 placed industrial investment in biotechnology-related R&D at U.S.$1 billion, roughly half of the amount of U.S. industrial spending (OTA, 1991). The Japanese have expanded their technological capabilities through acquisitions of mainly European biotechnology firms (e.g. 32 European biotechnology firms and one U.S. based firm were acquired by the Japanese during the period 1982-1988). In addition, the Japanese had joint ventures with several U.S. firms (some involving marketing arrangements with others involving research funding).

4.4.1.6 Developing Countries

The interest in biotechnology is not limited to developed countries. The governments of Korea and Brazil, for example, have targeted biotechnology as a priority sector. Shortages of trained personnel in biotechnology, however, are the key constraint in the development of the sector in these countries. Lack of IP protection is also cited as an important limiting factor.

4.4.2 Main Features of Biotechnology R&D

There are several interesting features of the structure of the international supply of biotechnology R&D and derived products:

(1) Important role played by governments and public sector institutions (mainly universities) in basic research that drives applied research by industry. In addition to their role in basic research, universities and government laboratories are dominant in developing applications in fields where commercialization is at its infant stage (most fields except medical and pharmaceutical applications, chemicals and biopesticides). This means that a significant share of the research in biotechnology is not driven by immediate commercial prospects.

(2) Dual structure of the commercial sector in North America. This structure consists of large diversified companies dominant in the market for commodity-type biotechnology products and small dedicated biotechnology companies that account for a significant share of the innovative applications. The existence of the small companies depends on their ability to protect the fruits of their research, yet signal its existence in the market. In Europe and Japan the large companies are dominant, perhaps because of the lack of a developed market for venture capital. Large companies have more flexibility in choosing means for protecting their IP.

(3) The large multinational companies primarily obtain new technologies through mergers and acquisitions and various alliances with the smaller dedicated biotechnology companies. An increasing number of large companies (mainly in the pharmaceutical and the chemical sectors) are establishing significant in-house research capabilities. Joint ventures across borders and foreign direct investment are leading to the globalization of biotechnology markets; however, the diverse regulatory regimes that govern the production and sale of some of the products of biotechnology create market niches for small specialized domestic companies.

(4) Because of the demand of large companies for R&D products (i.e. patents and know-how developed by others) a market niche for small firms specializing in the production of R&D has developed. Many of the small firms focus on the development of new patentable products or processes with the intention of selling the patents or shares to the larger firms. The larger firms acquire the patents to establish new product lines, to improve existing product lines or to defend existing product lines by suppressing competition.

In the next section we will describe in more detail the characteristics of the supply of biotechnology research and related products. We shall examine specifically the motives for the research, the types of risks associated with the research and the commercialization of the products and the barriers to entry. These include financial barriers, information and human resources barriers, and regulatory barriers. While the discussion may well apply to a wide range of biotechnology firms, we will concentrate only on those characteristics that predominate in the forestry-related application sector.

4.4.3 Underlying Motives for Biotechnology R&D

As indicated in the previous section, government funding (especially in health care in the U.S.) stimulated interest in universities and in-house government laboratories in basic biotechnology research. Objectives of the initial research programs were: (i) to elucidate DNA structure; (ii) to sort chromosomes and develop techniques for molecular cloning of large DNA fragments; (iii) to map genetic structures and develop techniques for tissue and cell cultures. Once developed, these generic tools of biotechnology created the opportunities for the development of a large array of applications. Graduate training associated with these basic research activities created the supply of professionals necessary for the evolution of the commercial biotechnology sector.

Research in universities (and to a large extent in government laboratories) is driven by a combination of motives including academic curiosity and priorities of the funders. Over time, as the share of government funding of university biotechnology research has declined, greater weight has come to be placed on the priorities of funders. Governments saw biotechnology as an engine for economic growth and encouraged both their own scientists and university scientists to seek the means for technology transfer to the commercial sector. As new technologies have emerged, so have new partnerships between agricultural, chemical, and pharmaceutical firms and universities. Initially cooperation was limited to research contracts, consulting and information exchanges. Later, formal joint ventures and partnerships were formed. At present, with the support of governments in Canada and the U.S., many university-industry cooperative research programs have been established. Some involve specific firms, while other programs involve an industrial consortium. As the visibility of biotechnology increased and venture capital became more available, universities (and university professors) sought to patent their inventions and market them through newly formed biotechnology firms. These firms continued the research with specific commercial targets in mind. In some instances, these targets have included specific products and customers. For example, a project to develop somatic seeds for specific tree species started by the British Columbia Research Corporation (B.C. Research) was motivated by the specific needs of companies such as Northwood. The improved seeds developed by B.C. Research offer a solution to pest problems that the firm encountered in its reforestation programs.

In other situations, the research is more speculative in nature, often with a target of developing a patentable product or a process that will draw attention to the firm and lead to eventual acquisition of its patents or the acquisition of the firm as a whole. In the biopesticides field, where more competitive "downstream" markets exist, "speculative" research without a specific client in mind is more likely to attract venture capital than ventures involving improved seeds, where competitive "downstream" markets do not exist. Specifically, seed markets involve either vertically integrated operations (the large companies produce their own seed) or largely government funded or controlled nurseries (supplying the smaller land owners). Furthermore, seed trade is restricted by geographical and environmental constraints that limit the application of seeds improved in one region for reforestation of another region. More recently the federal governments in the U.S. and Canada have encouraged their own scientists to obtain patents for inventions and seek commercial outlets to market them.

As we have previously mentioned, the threat posed by new biotechnological products to existing products has led many large multinationals to enter the field. Some have established in-house research divisions. These divisions provide the firms with a window on the biotechnological industry. In-house divisions were used initially as a mechanism to diversify risk by preempting new technologies that threatened major existing product lines. As the technology has matured and environmental regulatory pressures have increased (especially pressures to reduce the use of chemical pesticides), investment in biotechnology has become more attractive for the direct profit opportunities it presents.

Apart from in-house research, the large diversified firms are aggressively searching the market for new technologies. The search for technologies involves acquisitions, mergers and other forms of alliances with small R&D firms which possess promising portfolios of patents. The advantages of large firms in marketing and financing, as well as their economies of scale in production, give them a competitive advantage, especially in commodity products. Their deeper pockets give them an advantage in those fields of biotechnology applications that require lengthy processes of regulatory approval.

4.4.4 Entry and Financing

Entry to the R&D market is relatively easy, since it involves a fairly small initial capital investment (our interviews indicated that companies many start with about 3-4 professionals and capital equipment of less than half a million Canadian dollars).[13] Survival, however, is more difficult, since biotechnology companies use their cash reserves very rapidly. Trotter (1990), for example, suggests that it can take anywhere from $100,000 to $300,000 per year and consume up to three scientist-years to isolate and clone a recalcitrant gene. OTA (1991, p. 49) observed that "one of the reason that biotechnology companies use their cash reserves so rapidly is the intensity of R&D investment. Prior to product commercialization some companies dedicate 65% of all expenses to R&D. Estimates by Wall Street analysts are that the leading publicly-traded firms have a mean of just over 3 years and a median of 2.3 years of cash left, at either current or average burn rates. Past experience shows that the leading biotechnology companies have been extraordinarily successful in financing all of their cash flow needs. It is not clear how much longer this success will last, and there is evidence that a two-tiered structure has evolved among dedicated biotechnology companies, where leading firms are able to raise cash and the have-nots find resources increasingly unavailable". The U.S. trend is one of industry consolidation with a higher rate of entry accompanied by a rising rate of exit. "Venture capital has been available for biotechnology at the founding stage, but it is increasingly difficult to come by during the development stage, which is more expensive than the discovery stage" (OTA, 1991, p. 51). In Canada, venture capital is less available, and small companies rely on indirect subsidization by public funding through links with universities and government laboratories and through research and service contracts with industry.

Declining government R&D budgets and increasing competition for research funds means that some of the players in the public sector (universities and government laboratories) must now redirect their research to attract more private funding. Thus there is greater emphasis placed on more targeted research with specific clients in mind. The pursuit of private financing is bringing another element to the biotechnology game - the protection of proprietary information. While the traditional model of basic science is one of early dissemination of information (once it is verified), commercial interests play a role in delaying publication of research results.

In forestry-related applications, the problem of information dissemination is less serious than in other fields of biotechnology. There may be several reasons for this:

---

[13] Heller Consulting Inc. (op.cit., p. 25) estimates that sales per employee in Canadian biotechnology companies engaged in genetically modified lifeforms was $122,000 in 1993.

(1) the level of the present value of expected profits from particular inventions is relatively low, so the prospect of private funding is not significant;

(2) many of the research results (especially in the field of somatic seeds) do not have a universal application and often require a close relationship between the producers of biotechnology and the users (i.e. forest products companies, nurseries etc.)

(3) while the basic research elements of the application of biotechnology to forestry are well known, the "art" of processing and preparation of products is proprietary and is often protectable by secrecy.

In the following section we focus on the major suppliers of biotechnology and related products to the forest products sector.

4.5 The Supply of Biotechnology-Related R&D and Products to the Forest Products Sector in Canada and the U.S.

In an earlier section, we identified three broad areas where biotechnology can make a contribution to the forest products sector. In this section we describe suppliers of biotechnology R&D, and related products to the North American forest products sector. We do not discuss bioprocessing, since no potential uses of transgenic multicellular organisms exist in this activity.

4.5.1 The Activities

There is a distinct difference between the market for biopesticides and the markets for improved seeds and bioprocessing. The market for biopesticides is an integral part of the market for pesticides used in agriculture and forestry. As we shall argue below, forestry applications do not offer a large potential market, though forestry demand is playing a key role in the initial development of biopesticides. The markets for improved seeds and specialized bioprocessing require specialist suppliers with facilities dedicated to forestry or forest products technologies. The suppliers of somatic seeds include: (1) small dedicated biotechnology companies, (2) some research and nursery operations run by large forest products companies producing seeds for their operations but selling to others to benefit from economies to scale and exploit more fully their intellectual properties, and (3) publicly funded R&D establishments and nurseries. The suppliers of bioprocessing R&D encompass mainly cooperative research programs between universities and industry, industry cooperatives and in-house research in large pulp and paper companies. In contrast, the market for biopesticides is well developed with a significant presence of large diversified companies that produce both chemical and biological pesticides for forestry and agriculture. In this market, the role of governments in funding and producing applied research is rather minor; however, government funding of basic research that creates potential for long term application of biotechnology in pest control is significant.

The following section deals with the supply of biotechnology R&D in reforestation. It will be important to keep in mind the statistics of this section: while biotechnology may well be a vital component of future silvicultural efforts in Canada, at present even "classical" genetic improvement in Canada is in its early stages.

4.5.2 Biotechnology R&D in Tree Improvement Activities

As noted earlier, there are many potential benefits of somatic embryogenesis which translate directly into potential benefits for involvement in R&D activities. Beyond the benefits already mentioned, it should be added that there are a number of plant species, such as northern conifers, that are difficult to propagate naturally. Seed supply and/or germination can be inherently poor, and vegetative propagation difficult (and as a result very expensive). These considerations reduce any cost disadvantage the somatic process may have for such species.

At the same time, there are potentially high costs associated with somatic embryogenesis. For example, somatic seeds (somatic embryos encapsulated with a protective and nutritious coating) have not yet been developed successfully for northern conifers (artificial seeds of white spruce do germinate but require sucrose and a sterile environment - see Sutton, *et al.*, 1993). As a result, the technology at present requires *in vitro* germination followed by planting in a controlled environment, and then selling acclimatized seedlings. This lends itself to added cost as the seedlings during their controlled early development grow more slowly than natural seedlings. Once the somatic seedlings have acclimatized to nursery conditions, however, their growth has been shown to be comparable (Sutton, *et al.*, 1993). Mullin (1992), for example, in an extensive survey of the literature, found that vegetative propagation costs range from 1.5 to 10 times the costs of natural seedlings. Further, Mullin's own work determined that "true" clonal forestry, where tested clones are deployed, is only attractive financially when there is a substantial component of nonadditive genetic variance.

At the existing level of technology and the relatively small scale of somatic embryogenesis for most conifer species around the globe, it appears that cost is a significant factor in limiting the economic attractiveness of "producing" the technology. However, the cost structure can be expected to change with scale. Sutton (1993) at B.C. Research, for example, states that their cost per somatic seedling is approaching that of natural seed propagation (through their work with Silvagen in commercializing the process). Moreover, there is some evidence that the technology could be profitable in the future. To site an example, Tasman Forestry Ltd. in New Zealand has been operating a tissue culture laboratory since 1988, producing in excess of 2.5 million somatic Radiata pine seedlings per year. One would assume that they would not be involved at this level if it was not potentially profitable. Mullin (1992), using net present values to economically quantify benefits of the technology compared to the substantial assumed costs, found positive results for micro-propagation in some cases (even at relatively high discount rates), which clearly demonstrates the benefit of utilizing somatic technology, and the potential profitability of producing the technology.

4.5.2.1 Participants in Tree Improvement Biotechnology Activities

In 1988, BIOFOR (a national biotechnology network sponsored by the federal government) formed a Steering Committee and commissioned DeYoe and Scowcroft to do a study on the supply and demand for biotechnology in forest regeneration in Canada. This study resulted from a recognition by the Steering Committee that forest regeneration is an area which had received little attention in Canada.

> "The forest products industry is proactive in supporting development of new product lines and waste-treatment technology through agencies such as Forintek and Paprican. The forestry resources sector must adopt a similar approach if it intends to capture the benefits of biotechnology". (DeYoe and Scowcroft, 1988).

As part of their study, DeYoe and Scowcroft did a survey of the stakeholders in this field, including those involved in research. It was recognized that Canada has an international reputation in forest biotechnology, especially in micropropagation research. While it was noted that networking between research institutes was taking place (as an example, B.C. Research and UBC), it was also noted that "such networking must also include tree improvement programs, nursery culture, and intensive silviculture if biotechnology is to have a significant impact on forest regeneration. To stimulate forest industry involvement, cooperative ventures must focus on well characterized, operational problems to ensure that research has a practical outlet". Examples of this sort of cooperation do exist today, an example of which is the joint venture between B.C. Research and Silvagen.

Table 24 gives a list of institutions identified at the time of our survey as being engaged in seed forest biotechnology research in Canada. The only major commercial player in somatic embryogenesis in Canada is B.C. Research in Vancouver (Sutton, 1994). In fact, B.C. Research has the distinction of being the only player in the world for northern conifers. Its efforts have focused on Interior Spruce due to the difficulty encountered in the natural propagation of this species (as is the case with most northern conifers). Under the umbrella of B.C. Research is the Forest Biotechnology Centre, created in 1986 through funding from B.C. Research, the B.C. Ministry of Forests and Forestry Canada. This Centre is an interdisciplinary research group focusing on "the development and application of advanced technology for the enhancement of forest regeneration and productivity" and on specific projects "aimed at the development of proprietary technologies in genetics and propagation" (Sutton, 1994). The centre consists of a staff of 16 scientists in the fields of biotechnology and forestry. Collaborative efforts with government and university laboratories greatly enhances this resource, as do joint ventures with industrial partners. This includes a venture with Silvagen Inc. and Pelton Reforestation (a private nursery near Maple Ridge, B.C.) for commercializing Douglas fir emblings. B.C. Research also does contract projects for industry. An example is a two year project, funded by many of the large B.C. forest companies, to produce cloned Sitka spruce emblings from insect-resistant families.

Although B.C. Research focuses on British Columbia, it does contract research for clients from other parts of Canada, the U.S. and 25 other countries.

The principal areas of research carried out by the Forest Biotechnology Centre related to forestry applications are as follows:

1) **Tissue Culture.** The main emphasis here is with somatic embryogenesis, including mass propagation of superior stock from tree breeding programmes and the selection of superior clones. B.C. Research to date has cloned primarily from existing species (i.e. limited genetic engineering). They have approximately 1000 clones for selection, which at 5% selection intensity yields 50 clones which they use for production. (For reasons of genetic diversity, it is important that cloned varieties are relatively high enough in number). By the end of 1993, B.C. Research had produced roughly 50,000 plants somatically for trials. Thanks to a joint venture with Silvagen Inc., emphasis has since turned to production on a commercial scale. In 1994, production is expected to exceed 100,000 plants, with a view to increasing this number to over a half million plants over the next two years. The stated commercial emphasis is the delivery of an Interior Spruce seedlings (or "emblings") which have genetic resistance to insects and superior growth rates.

   Forest companies have funded R&D through B.C. Research as well. A recent example (1992) is somatic reproduction of limited seeds available from particular Sitka spruce trees which have been identified by the B.C. Ministry of Forests as being resistant to the terminal weevil. The somatic embryogenesis was funded by Western Forest Products, Canadian Pacific Forest Products, MacMillan Bloedel and International Forest Products. Additional funding was provided by the Ministry and the National Research Council of Canada's Biotechnology Contribution Program. B.C. Research's emblings are growing in beds at Pelton Reforestation Ltd. in Maple Ridge.

2) **Molecular Genetics.** As mentioned earlier, molecular genetics involves not only genetic engineering, but also the development of markers or DNA "fingerprints" which can be used to analyze natural hybrids and monitor seed orchards (monitor pollen contributions, contamination and inbreeding). In the area of genetic engineering, improvement of clonal material is a long term goal of the Centre. However, it has recently reported successful genetic engineering of somatic spruce seeds "injected" with a gene isolated from the bacterium B.t. to create resistance to spruce budworm (B.C. Research, 1992). This accomplishment included a trade mark registration of the "ACCELL™ DNA delivery system" used to introduce the foreign genes into the interior spruce's somatic embryo.

3) **Pathology and Microbial Inoculants.** Efforts here relate to both biological and cultural approaches to enhancing conifer seedling health and growth by controlling fungal disease. The Centre has identified a number of microbial strains for biological control and is in the process of commercializing them.

4) **Physiology Assessment and Modelling.** The Centre has developed a method of physiological and morphological measurement of such traits as drought and frost tolerance, growth capacity and photosynthetic capability. This is of great use in identifying optimal nursery culture and planting regimes. Several of the Centre's clients use these measures as a support service for their seedling markets.

There are a number of non-commercial research centres in Canada that do considerable research in tree breeding technologies. Two of these are the Petawawa National Forestry Institute (Canadian Forest Service, Chalk River, Ontario) and the Plant Biotechnology Institute (National Research Council, Saskatoon, Saskatchewan). Further, the Plant Biotechnology Institute, the Petawawa National Forestry Institute and the Forest Biotechnology Centre have officially agreed to collaborate on research in conifer tree biotechnology.[14]

The Petawawa National Forest Institute has been researching tissue culture since 1985, with successful somatic embryogenesis in hybrid larch. It is now looking at the process of producing a somatic "seed" (encapsulating somatic material) for white spruce through collaboration with scientists at the University of Guelph.

The Plant Biotechnolgy Institute in Saskatchewan is one of four research centres making up the NRC's biotechnology program. The others are the Institute for Biological Sciences in Ottawa, the Biotechnology Research Institute in Montreal (see section on biopesticides) and the Institute for Marine Biosciences in Halifax. Only the Saskatchewan centre does research applied to seed plants (and primarily for agricultural plants). Forestry related research is produced by their Conifer Biotechnology Group, the aim of which is "to develop conifer biotechnologies for application in the multiplication and genetic improvement of forest trees. Their current research goals are to develop reproducible propagation and genetic transformation methods. Research is directed toward a more complete understanding of regeneration systems, toward optimization of stable transformation, and toward isolation of conifer gene sequences" (NRC Plant Biotechnology Institute Annual Report, 1993).

The Canadian Forest Service has other research centres as well (eight in total), including the Pacific Forestry Centre which services B.C. and the Yukon. Although a significant level of research is produced by this centre in the area of molecular genetics, the vast majority of their staff work in the area of bio-pesticides.

There is no biotechnology research being performed by the provincial ministries of forestry. The Research Branch of the B.C. Ministry of Forests, for example, has a Forest Productivity Branch which does research into the value of incremental silvicultural techniques (e.g. pruning and spacing), and a Forest Renewal Branch which focuses on classical genetics only. Much of the work this group is doing is related to pedigree selection in Sitka and Interior Spruce for resistance to spruce weevil. They do some work, however, in the area of molecular genetics, primarily in the utilization of markers and probes for parental trait identification techniques. Their work in this regard is quite applied; i.e. aiding seed orchards in their testing and breeding programs. The Silviculture Branch of the B.C. Ministry includes the Forest Health Section, the Nursery Services Section and the Seed Services Section. The emphasis of these groups is even further removed from research, having more of an extension role.

---

14 The March 1995 federal government budget indicated that the Petawawa National Forestry Institute will be closed.

In the United States, there are a number of institutions doing work on somatic embryogenesis, all on Douglas fir and Loblolly pine. These includes the USDA Forest Service, with research facilities in Reinlander, Wisconsin; Berkeley, California; and Gulf Port, Mississippi; universities (notably the University of Washington working on poplars), and private industry, most notably Weyerhauser in the Pacific Northwest and Wesvaco in the South.

Internationally, the only large scale research in somatic technology is taking place in New Zealand on Clonal Radiata pine plantations. The research is headed by the Biotechnology Division of the Tissue Culture Research Group at the New Zealand Forest Research Institute. As mentioned, this has resulted in the commercial production of over 2.5 million Radiata somatic trees being planted annually, through commercial association with Tasman Forestry Ltd. The research group has more recently developed a somatic embryogenesis process that can be applied to pines and Douglas fir. This process is currently under evaluation by the New Zealand company Carter-Holt-Harvey Forests (Smith, 1994).

4.5.3 Biopesticides and Herbicide R&D

Each of the major private firms involved in production and marketing biopesticides is also actively involved in R&D. Most of the efforts focus on identifying new strains of B.t. and improved preparation. Bioengineering is used to improve the effectiveness of the biopesticides in terms of specific target controls. The ultimate aim of R&D, however, is to develop biopesticides which are effective for agricultural use. The market for pesticides in agriculture is much more lucrative and stable than the market for pesticides for the control of forest pests.

Some government establishments both in Canada and the U.S. also focus on B.t. Others are exploring the use of other microorganisms for the delivery of toxins. Generally the research of government R&D establishments is focused upon longer term applications, as well as less commercially attractive market niches such as the development of bioherbicides.

One of the largest groups in the world doing research on bioherbicides applied to forestry is the Canadian Forest Service's Pacific Forestry Centre (PFC) in Victoria, B.C. The research done at the PFC is mostly targeted at biological control of forest weeds and disease (such as fighting root rot) as opposed to biological control of insects. Private and public funding, however, is more available for bioinsecticides R&D - presumably because the end result is more visible and therefore easier to market (killing off a countable number of insects, for example, is more visible than preventing root rot).

The PFC has successfully developed three bioherbicides. The first is *Chondrostereum purpureum*, which is used in the control of hardwood "weeds". While the idea of using this organism as a biopesticide is not new, PFC is working on improved formulations which could be patentable. The second is *Nectria sp.*, which is also used for undesired hardwood regeneration, but limited to Red Alder as its target. Finally, the PFC has developed *Colletotrichum sp.*, used for the bio-control of Canada reedgrass (for use in boreal spruce and pine plantations).

The prospects for bioherbicide marketing are somewhat dimmer than for biopesticides, since bioherbicides (unlike biopesticides) tend to be considerably more expensive than chemical pesticides. In spite of the fact that bioherbicides are environmentally friendly and attack only specific targets (unlike chemical herbicides which tend to be relatively indiscriminant), most forest companies are not willing to pay the added cost, since they do not internalize the environmental benefits. Thus the commercial prospects for bioherbicides depend largely on regulatory intervention designed to protect the environment or to ensure a healthy forest.

However, provincial hydroelectric companies from many of Canada's provinces have been more willing to provide funds for cooperative development ventures, since they have a need to control vegetation under hydro lines in an environmentally safe manner (due to proximity to urban areas, watersheds, etc.) The Canadian Electrical Association (an umbrella organization for the provincial hydro companies) is negotiating with the PFC and an outside chemical company for commercialization of the three bioherbicides that PFC has already registered (Blain, 1994). As a general rule, however, industries have not tended to be in favour of such joint ventures unless the vast majority of the R&D has already been completed by the publicly funded R&D establishment (e.g. the PFC).

Aside from the PFC, the Canadian Forest Service also has facilities doing research in biopesticides in other parts of the country. Most notable is the Forest Pest Management Institute in Sault Ste. Marie, and the Petawawa National Forestry Institute in Chalk River, both in Ontario. The National Research Council of Canada is also a noted player in the area of biotechnolgy in pest control, with significant R&D effort at the Biotechnology Research Institute in Montreal, Quebec.

There is little R&D on biopesticides done at the provincial level. The important activity at this level is the diffusion of innovation through the extension operations of the Forestry ministries.

In the U.S., only one of the U.S. Forest Service laboratories is experimenting with B.t. However, their focus is on naturally occurring bacteria and not on engineered organisms. Applied research on biopesticides in universities is usually conducted cooperatively with industry. Basic research on the mechanisms involved in controlling pest populations and the development of new strategies for pest controls is conducted in universities in both Canada and the U.S.

4.6 Some Preliminary Conclusions and Observations

This preliminary report identifies several factors which are relevant to the analysis of IP protection policies.

1) Significant commercialization of improved bioengineered seeds that increase growth or quality (multigene interventions) is likely to occur no earlier than 20-30 years from the present. Biotechnology, however, can be used to enhance and shorten traditional breeding techniques. Significant commercial development of genetically engineered seeds with traits controlled by a single gene is likely to occur within ten years.

2) The long term nature of tree improvement benefits and the uncertainties involved in the R&D process imply a relatively low present value for many of these innovations. "Insurance" innovations (e.g. protection from pests and fires) and innovations which reduce costs of reforestation (i.e. innovation with benefits that can be realized in the short run) are most likely to be the targets of innovative activities of commercial enterprises.

3) Biopesticide R&D will continue in the next decade to focus on unicellular organisms (particularly B.t.) However, the potential for introducing multicellular bioengineered predators does exist. (Research on the use of multicellular bioengineered pest control agents is likely to be centred during this decade in universities where IP protection is less important than for profit-oriented companies).

4) Environmental regulations provide an important incentive for R&D in the biopesticide field. Forest management regulations are the driving force for much of the effort in seed improvement in Canada. Environmental regulations, however, may slow the introduction of bioengineered tree seeds in Canada and the U.S. (other countries with less stringent environmental controls, such as China, are likely to be targeted as export markets for improved seeds). Biotechnology, in combination with traditional genetic selection methods, will allow faster generation of improved seeds (the importance of protecting new tree varieties will thus increase).

5) The markets for biopesticides and seeds differ significantly in the type of incentives that exist for innovative activities. Tenure systems are especially important in shaping incentives for the R&D of tree improvement.

6) Different research cultures characterize public and commercial R&D establishments. These differences explain in part the market structure and division of labour in the R&D process. They also create different responses to incentive and regulatory systems (e.g. different preferences for IP protection policy attributes).

7) The requirements for IP protection and the preferred strategies used by different types of companies engaged in biotechnology R&D for forest products applications differ. Large forest products companies in the U.S. have vertically integrated forestry operations (including seed generation) and have only limited interest in significant sales of seed. Typically the use of trade secrets and sale contracts offer them sufficient IP protection. Small dedicated biotechnology companies in both Canada and the U.S. depend on patents to ensure a return on their R&D. To the extent that small dedicated biotechnology companies wind up doing most of the commercially oriented R&D, IP protection becomes a more important consideration. In Canada, provincial governments have the major interest in tree improvement but as the major consumer of tree seeds, they also have an interest in lowering costs (and consequently might prefer lower IP protection).

5.0 ECONOMIC CONSIDERATIONS

There are two broad generic policy issues surrounding the patenting activity. One concerns the issue of how much to reward a patent. In principle, public policy can influence the *ex ante* returns to invention by modifying the intellectual property regime surrounding commercial inventions. Put imprecisely, "strengthening" the intellectual property regime enhances the ability of the inventor to invoke legal remedies to prevent direct or indirect appropriation by another party of the commercial benefits inherent in the invention. This, in turn, presumably augments the expected profitability of the invention in question to the patent holder. Conversely, "weakening" intellectual property protection enhances the ability of parties other than the inventor, including possibly consumers and rival producers, to appropriate a greater share of the commercial benefits of a given invention which, in turn, reduces the expected profitability of a given invention to the inventor.

In more general terms, the design of patent law is fundamentally concerned not simply with promoting original innovations but rather with promoting the overall net benefits of the stream of potential primary and secondary innovations linked to specific research and development (R&D) outcomes. Hence, the patent protection regime is relevant both as it influences early innovations, as well as the improvements to early innovations embodied in follow-up innovations. From a social welfare perspective, rewards to patents should be set so that the social benefits of an additional invention exactly equal the social costs. In more general terms, rewards should encourage neither too much nor too little overall inventive activity.

A second issue is concerned with how to reward patent holders. The relevant literature describes a potential tradeoff in two dimensions: length of time for which the underlying intellectual property is protected and breadth of coverage of the protection.[15] The first dimension is obvious. A longer period of protection can be expected to increase the expected profitability of an invention all other things constant. The second is less obvious. One conventional definition of patent breadth equates it with the scope of substitute products or processes covered by the patent. Broader scope implies that a wider range of potential alternatives would be considered to infringe the patent in question (see Klemperer, 1990). A more general definition equates patent breadth to the flow rate of profit available to the patentee while the patent is in force (Gilbert and Shapiro, 1990). The larger the flow rate of available profit, the broader the scope of patent protection. Flow rate of profit, in turn, is influenced by the range of potential alternatives that would be considered to infringe the patent, as well as the nature of any restrictions on the exploitation of the patent. In particular, the "originality" requirements imposed on potential patentees are related to patent breadth. If broad patent protection is granted, the originality requirement imposed on would-be imitators is relatively high. If narrow patent protection is granted, relatively derivative second generation products may be found not to infringe the original patent. Hence, we will consider originality requirements to be subsumed within the patent breadth decision which is consistent with

---

[15] A more comprehensive discussion of these two potential dimensions of patent protection, as well as alternative definitions of patent breadth can be found in Richard Gilbert and Carl Shapiro, 1990.

the literature (Scotchmer, 1991). Indeed, patent breadth and length are interrelated, since the effective life of a patent is determined by when a non-infringing rival appears.

Flow rate of profit will also be affected by the ability of the patentee to restrict usage of the patent by licensees or by other discriminatory provisions. At one extreme, there may be no restrictions on the patentee arrangements, tying arrangements or other commercial transactions to exploit a patent. At the other extreme, there may be tight restrictions on the exploitation of a patent including compulsory licensing at "reasonable" fees. The inference one can draw is that the weaker the set of restrictions, the larger the flow rate of available profit and the broader the scope of patent protection. Flow rate of profit may also be affected by rules governing the pooling of patent or other cooperative initiatives, such as R&D joint ventures.

From a social welfare perspective, patent holders should be rewarded efficiently. To the extent that rewards to patentees represent an implicit tax on potential users of the patent, rewards should be structured so as to minimize the "deadweight" costs of the tax.[16] Much of the literature on patenting is concerned with identifying the conditions under which narrow and long-lived patent protection is likely to have lower deadweight costs than broad and short-lived patent protection (Gilbert and Shapiro, 1990; Klemperer, 1990; Gallini, 1992).

Hence, consideration of patent policy in the context of any specific economic activity is ultimately concerned with the issues of the appropriate magnitude of patentee rewards and how the rewards are structured. As a general statement, one can equate patentee rewards to longer and broader patent protection. Conceptually, a given reward can be structured by choosing different combinations of patent length and breadth. Before elaborating upon these issues and setting them in the context of forestry biotechnology, we review the basic social welfare tradeoff associated with increasing or decreasing the rewards to patentees.

5.1. The Social Welfare Tradeoff

The essential nature of the social welfare tradeoff is illustrated by Figure 3. In this figure, Q represents the output emanating from a production process, while P represents the price of the output.[17]

It is assumed that the initial cost of production is C_0. With price equal to C_0, total consumer surplus is DAC_0. It is then assumed that an innovation emerges which reduces the cost of the good in question to C_1. Further, assume initially that the invention yields a royalty of $(C_0 - C_1)\,Q_0$ per period during the term of the patent. At this royalty rate, the patented process is the cost equivalent of the existing unpatented technology. Then C_0ABC_1 is the surplus to the inventor. Once the patent

[16] Deadweight costs can be thought of as reductions in consumer and producer surplus associated with trying to avoid the incidence of a direct or indirect tax.

[17] The basic model described here was developed in Nordhaus (1969). It has been used in McFetridge and Rafiquzzaman (1986), and Sharma (1993).

expires, the royalty falls to zero and competitive cost in the user sector falls to C_1. There is a transfer of surplus from the inventor to consumers in the amount C_0ABC_1 and a gain in consumer surplus of ABE.[18]

All other things the same, the sooner the patent expires, the sooner society gains the consumer surplus of ABE; however, if patent protection is insufficient *ex ante* to cover the cost of inventing, including the required return for risk bearing, the invention will presumably not be forthcoming, and society will lose the entire surplus C_0AEC_1. The "ideal" patent policy in this case is to provide rewards to the inventor just sufficient to induce the introduction of the technology. In some circumstances, this might imply royalty payments per period of less than $(C_0 - C_1)Q_0$. Indeed, if the invention has already been introduced in another country, or if the domestic market in question is very small relative to the world market, domestic patent policy may have no influence on the rate at which new technology becomes available to the domestic market. All other things constant, this would imply providing no patent protection for inventions as a first-best policy. In fact, other things are unlikely to be constant. For example, adopting a non-protection policy might provoke retaliation in kind, or in other dimensions of trade, by trading partners, if the latter offer strong protection of intellectual property.[19] Hence, there may be broader international relations considerations affecting patent policy which suggests that identification of patent regimes among Canada's trading partners is a relevant part of any analysis of domestic patent policy.

5.1.1 Ownership and Competition

Notwithstanding the caveat about a country's broader international relations, it is appropriate to argue that "overcompensating" patentees is of greater concern when the patentees are non-residents. In this case, rewards above the minimum required to reveal the technology represent transfers from domestic consumers to foreign patentees. On the other hand, any income transfer from foreign patentees to domestic residents represents a domestic surplus gain. Whether the surplus is captured by domestic producers or domestic residents depends upon competitive conditions in the market in which the invention is used. For example, imagine that a process innovation is used in an industry in which domestic producers are essentially price takers in the world market. That is, they represent a relatively small proportion of the output produced in that industry. In this case, patent protection for the process elsewhere will keep the world price of the product using that process "high". This implies that domestic producers in the country not providing patent protection will earn economic rent for some period of time, since their unit costs of production will presumably lie below the world price for the product. On the other hand, if domestic producers are price makers in the world market, the lower costs associated with the

---

[18] The relevant surplus values would presumably be discounted to present value terms. An important assumption is that the patentee cannot price discriminate so that the consumer surplus ABE was capturable in the first place by the patentee.

[19] This point is made forcefully in Sharma (1993). It is unclear whether any foreign retaliation would be widespread or in-kind, i.e., focused on intellectual property assets. Recent U.S. actions for alleged violations of U.S. intellectual property in China covered a wide range of goods.

process innovation will be passed on to consumers in the form of lower prices (see McFetridge and Rafiquzzaman, 1986).

The income distribution effects of patent policies can become quite complex in the context of the discussion in the preceding paragraph. For example, if domestic producers are actually foreign-owned affiliates, any transfer of income to them from patentees may not represent a gain in domestic surplus. As another example, final consumers may actually be foreigners to the extent that the domestic industry primarily exports its output. In this case, any pass through of cost savings to consumers would represent income gains for foreigners. The point underscored by this discussion is that the domestic welfare effects of patent policy may be importantly conditioned by the market structure of the industry that uses the patented process or product, as well as by the nationality of the producers and consumers of the outputs of that industry.

The social welfare consequences of "over compensating" patentees is also affected by the nature of competition in the patenting process itself. For example, at one extreme, the patentee may possess unique attributes such that it is the only firm working in the technological domain covered by the patent. In this case, the patentee can presumably appropriate all of the economic rent associated with excessive compensation under the patent regime. Alternatively, the patentee may be only one of numerous firms with the potential to work in the relevant technological domain. In this case, the existence of potential economic rent associated with the patent regime will encourage "competitive patenting" which will dissipate (in equilibrium) all of the economic rent associated with the over-compensation of patentees.[20]

In terms of Figure 3, if the entire area C_0ABC_1, is assumed to be economic rent in each period during which patent protection is in place, competitive patenting will generate real resource costs equal to C_0ABC_1. Note that this represents real costs to the economy and not simply income transfers. Simply put, if the patent regime is overly generous in rewarding patentees, social welfare may well be reduced if competitive patenting is encouraged. This, in turn, depends upon the specificity across firms in technological skills. The more generic the skills required for the technological regime, the greater the competitive patenting. It may also depend upon the ability of firms to restrict competitive patenting through cross-licensing agreements and the like.

5.1.2 Dynamic Considerations

Much of the literature dealing with patent rivalry assumes that direct competition ceases once the patent is granted.[21] Rather, a range of inferior substitutes is assumed to exist which limits the ability of patentees to extract royalty from users of inventions. The stronger the substitution possibilities, the tighter the limits. In effect, the existence of stronger (non-infringing) pre-existing substitutes limits the ability of the patentee to appropriate profits from its invention. All other

---

20 Such patent competition can obviously be socially wasteful if much of it is costly replication of what could be disseminated at lower cost.

21 A notable exception is Gallini (1992).

things constant, pre-existing substitutes render any patent regime effectively weaker compared to a situation in which no such substitutes exist. This, in turn, suggests that any given patent regime is less likely to be overly generous when a range of pre-existing, relatively strong substitutes exists for the invention. The implication is that policymakers should worry more about not compensating enough rather than compensating excessively when pre-existing substitutes exist.

In fact, it also seems likely that new competition will emerge following the introduction of a patented invention. Specifically, rivals to the patentee will seek to introduce non-infringing substitutes into the market. The implications of post-patenting competition are potentially quite complex. A basic argument maintains that it is inefficient to allow unbridled post-patenting competition. One reason is that much of the activity might be duplicating which generates the same welfare costs as those associated with pre-patent competition.[22] A second is the claim made by some observers that it is efficient for one firm to "control" technological development of a basic scientific breakthrough, both over time and across different applications. The relevant notion here is that the net benefits of scientific and technical work in period t depend upon scientific and technical work undertaken in prior periods, and that transactions costs and other market imperfections make it difficult for separately owned firms to internalize the relevant information in going from one stage of development to another.[23] A longer (through time) and broader (in scope) range of patent protection would contribute to less fragmentation in the ongoing development of any given invention.

One counterargument to the control argument is that the efficiency with which any new technology is developed to its full commercial potential is promoted by a "competition" of ideas. This is equivalent to saying that there are relatively low costs in diffusing information across potential innovators such that knowledge gained by firm i in period t can be virtually as valuable to firm j in period t+1 as it is to firm i in period t+1. In this case, discouraging post-patenting competition may reduce long-run rates of technological change.[24]

Certainly, some post-patenting activity will be duplicative; however, if competition promotes the efficient development and extension of given technologies, duplication is not necessarily wasteful. Moreover, if there is a wide diversity of tastes and preferences in the market such that new products primarily attract new customers, the welfare costs of duplication may be quite low (Waterson, 1990). Equivalently, if directions that future development efforts should take are unclear, and if firms have different R&D capabilities and specialties, it may be more effective to

---

[22] Again, the relevant assumption is that what is duplicated involves replication of something that could be diffused between firms at lower cost.

[23] It is not always explicit in the literature why "end-to-end" control of technological developments is more efficient than fragmented control. For one fairly extended discussion, see Merges and Nelson (1990).

[24] Nelson (1990) argues that history supports the conclusion that technical advance has generally proceeded much more rapidly in settings where a number of competitors were involved than where one or a few parties controlled development. Scotchmer (1991) agrees that since the first innovator is unlikely to have expertise in all applications, more second generation products are likely to arise if more researchers have incentives to consider them.

have different firms undertaking specialized R&D efforts, rather than have the original patentee undertaking a portfolio of technological initiatives.

In summary, post-patent competition can be discouraged in part by expanding the scope of patent protection and/or by lengthening the period of patent protection for the relevant invention. Post-patent protection has the effect of increasing returns to the patenting activity which, in turn, should stimulate technological competition at the pre-patent stage. Therefore, there is a potential tradeoff between pre and post-patent competition. To the extent that post-patent competition stimulates a faster rate of technological change and, moreover, to the extent that users of the patented innovation have diverse tastes, it may be preferable to encourage post-patent competition through narrow patent protection regimes, particularly if reduced rewards in the post-patent stage do not significantly discourage R&D investments in the pre-patent stage.

5.1.3 The Policy Issues

Perhaps the most fundamental public policy question is whether rewards to patenting in general, or in any specific scientific activity are too low or too high. Policymakers face two types of potential errors: (1) they can be overly generous in rewarding patentees which will delay benefits to consumers and encourage "patent races" which can be wasteful, (2) they can fail to reward patentees adequately, which will reduce inventive activity and deprive society of the entire surplus associated with specific foregone inventions.

Therefore, in addressing patent policy, several broad considerations must be confronted:

(i) What *ex ante* rates-of-return are potential inventors looking for in specific scientific activities?

(ii) How important is patent protection to achieving those *ex ante* rates-of-return?

(iii) What is the likely distribution of economic surplus among patentees, producers and consumers for given levels of protection?

(iv) What is the likely distribution of economic surplus between foreign and domestic residents?

(v) What is the likely nature of pre and post-patent competition?

(vi) How will foreign governments react to specific national patent policies?

5.1.4 Possible Scenarios

With respect to the first item, it is possible that inventors, in many cases, will accept *ex ante* rates-of-return that are no higher and, indeed, even lower than average rates-of-return to capital in more conventional economic activities. For example, in some scientific activities, the most likely inventors for the foreseeable future may be universities, government laboratories and other non-profit research centres. To the extent that these participants are not looking for economic returns in performing research, there is much greater scope for patent authorities to err on the side of providing too low a reward to patenting.[25] In other words, there is a stronger argument for limiting both the period of patent protection, as well as the scope of patent protection, all other things constant.

With respect to the second item, it may be the case for many inventors that good alternatives exist to patents as a way of protecting relevant intellectual property. One obvious possibility in this regard is trade secrecy. Trade secrets are protectable under common law and have no time limitation, except that once the secret becomes common knowledge, it is no longer protected. Another is idiosyncrasy combined with complexity. Simply put, it may be difficult for any firm without the requisite skills and experience of the inventor to "reverse engineer" the invention.

Patents may also be relatively unimportant to the invention process because the life-cycle of the underlying product or process under protection is relatively short. Rather, commercial returns are largely a function of how quickly new products or processes can be introduced into the market. In this circumstance, trade secrets are more likely to be relied upon, or, possibly, no formal intellectual property protection at all. Conversely, if the commercial benefits of an invention are realized only over a very long period of time, patent protection may be relevant, but only if the authorities are willing to grant relatively long patent terms. Even then, the present value of the returns may be relatively low, so that strengthening or weakening patent protection has little influence on inventing behaviour, on the margin. What seems most likely in cases of long-gestation technologies is that universities, government labs and the like will be the major sources of research.[26]

Even if the patent regime is unimportant to achieving required *ex ante* rates of return to innovation, it may have important consequences for economic efficiency if it encourages or discourages earlier publication of research findings. For example, early publication of findings might discourage competitors from duplicating research already done. Early publication might also

---

[25] Equivalent, potential public sector patentees may also be the largest potential users of the relevant innovations, in which case they can appropriate the benefits of their innovation activities in their roles as users.

[26] A related variation of this approach might have government contract-out research to private R&D laboratories. The economics of contracting-out R&D and related activities is beyond the scope of full consideration in this study. Suffice to say that the transactions costs and risks of opportunism associated with the contracting-out of R&D are relatively high. Moreover, private cost-plus contracts themselves invite opportunism. Certainly, governments can and do contract out basic and applied research (e.g., university grants), as well as development activities (e.g., computer systems development); however, contracting-out R&D with retention of the commercial applications residing with the government funding agency is an unusual and, arguably, high problematical arrangement.

stimulate new, promising lines of research (Scotchmer and Green, 1990). In such cases, if stronger patent protection encourages firms to patent rather than rely on trade secrets, it might have social benefits associated with revelation. At the same time, inventors have an incentive to announce technological breakthroughs to encourage competitors to drop out-of-the market. So patent protection may not be required to discourage competitive duplication of research or to signal promising new lines of research.

The stronger the patent protection granted an invention, the larger the surplus captured by the patentee. The weaker the protection, the larger the surplus captured by producers and/or consumers, presuming that the nature of the invention itself is unaffected by the nature of patent protection. If all participants are domestic residents, national surplus is enhanced by weaker patent protection as indicated in Figure 3; however, if consumers are foreigners, say served through exports, or producers are primarily foreign-owned affiliates, national surplus might actually decline with weaker patent protection. This latter observation highlights the importance of identifying whether specific participants are foreign or domestic residents, i.e. item (iv).

The stronger the potential for pre-patent competition, the stronger the argument for erring on the side of under-rewarding invention. By doing so, patent policy mitigates the risk of competitive races for invention with costly duplication of research.[27] Moreover, if post-patent competition promises to stimulate subsequent innovation, and if the relevant market is characterized by diversity of tastes and preferences, the argument is again on the side of erring in favour of under-rewarding invention.

Finally, with respect to the last item, if foreign governments have implemented strong patent protection regimes, any individual country proposing a weak regime courts closure and possible retaliation. On the other hand, if the specific area of scientific activity is relatively specialized and not of great interest to other countries, retaliation may not necessarily be automatic or severe.[28] In this case, a small country such as Canada is almost certainly likely to benefit from a weak patent protection regime, since it will benefit disproportionately from avoiding the payment of royalties to foreign patentees (Berkowitz and Kotowitz, 1982).

---

[27] We emphasize again that duplication (in our discussion) implies that the costs of any new information generated exceed the associated social benefits.

[28] It is impossible for us to speculate about whether foreign pressure would exist to provide patents on forest trees, *per se,* or whether such pressure would only follow as a result of general patent protection being available on plants. Nor can we speculate about whether complaints would be raised by discriminating against particular types of plants related to a particular use (e.g., food). As a matter of experience, exemptions or other manifestations of discrimination raise strong objections when they appear to be targetted at specific foreign interests.

5.1.5 Summary of Factors Conditioning the Welfare Tradeoff

Figure 4 summarizes a set of factors conditioning the likelihood of any patent regime providing protection that is either "too strong" or "too weak". In the context of Figure 4 and the preceding discussion, protection is too strong if a narrower scope of patent protection or a shorter period of protection would increase net social benefits. Conversely, protection is too weak if a broader scope of patent protection or a longer period of protection would increase net social benefits.

The likelihood that any given degree of patent protection will be too strong is increased by the presence of a relatively large number of potential innovators, since this condition strengthens the probability of wasteful (or excessive) pre-patenting competition. It is also increased to the extent that consumers cannot easily substitute away from the patented product (or process) or the set of products or processes ultimately protected by patents, since the patentee(s) can impose a relatively high price-cost markup on consumers.

A third factor is the nature of the technological change process itself. If the direction of technological change is unclear, so that there are alternative paths that might be taken, strong patent protection might unduly limit the number of participants doing "follow-up" R&D. This problem is accentuated if the original innovator is unwilling or unable to license its technology to follower-firms. Finally, protection is likely to prove too strong if government is already a relatively large funder of R&D. In this latter case, the profits generated by patent protection may be pure rent, in that they stimulate little or no additional R&D while redistributing income from broad groups of consumers to narrow groups of producers.

The likelihood that any given degree of patent protection will be too weak is positively related to the ability of rivals to appropriate the commercial benefits of the innovation in question through for example, reverse engineering. It is also positively related to the number of firms capable of performing follow-up R&D, especially when the potential improvements are likely to be quite modest, since this condition is likely to lead to inefficient post-patent competition. Finally, if intellectual protection is strong elsewhere, weak protection in a given country raises prospects of retaliation, perhaps in other areas of international trade.

5.2 General Evidence on the Patenting Process

In this section of the report, we review some general evidence on patenting processes with a view towards providing insight into the main issues identified in the preceding sections. In the section following this one, we assess salient features of the biotechnology industry (with an emphasis on forestry biotechnology) to evaluate whether findings from the general literature are likely to apply to the biotechnology sector, or whether they must be modified to reflect specific features of biotechnology research and commercial application.

5.2.1 Rates of Return to R&D

There are a host of studies identifying private and social rates of return to R&D across a range of industrial sectors. Evidence on these rates of return may provide indirect insights into the role of patents. In particular, to the extent that observable differences between private and social rates of return can be related to the importance of patent protection, inferences that patent protection affects the distribution of benefits from new technology would be supported. Conversely, if private rates of return to R&D, as well as differences between private and social rates of return to R&D are unrelated to patent protection, it would call into question the significance of patents as determinants of appropriability.

In fact, there is very little direct evidence on the interaction between private and social rates of return to R&D and patent protection. In one study, Cockburn and Griliches (1987) examined whether the stock market values the accumulated patents and the current R&D policy of a firm more or less in industries where the appropriability conditions are better. In this regard, patent effectiveness measures help in some sense. That is, both accumulated past patents and current R&D moves are valued more by the market when patent protection is effective. Interestingly, other appropriability measures do not help. However, neither set of appropriability measures does any better than simply interacting stock market values with industry dummy variables suggesting that patent protection may be a proxy for other factors conditioning stock market values (Cockburn and Griliches, 1987).

More unambiguous support for the importance of patenting as a vehicle to enhance appropriability is provided by specific research on the drug industry. For example, there is evidence that changes in the compulsory licensing laws regarding patented pharmaceuticals affect stock market valuations of pharmaceutical companies. Such evidence is consistent with evidence discussed in the next section which underscores the subjective importance of patents in the pharmaceuticals and chemical industries.

5.2.2 Subjective Importance of Patent Protection

The literature on this issue is quite consistent in concluding that with the exception of a few specific industries, patent protection is not seen as an important determinant of rates-of-return to invention. One representative study is based on a questionnaire sent to a large sample of manufacturing multinational enterprises (Wyatt and Pavitt, 1985). Firms were grouped into five main sectors: pharmaceuticals, other chemicals, electronics, mechanical engineering, autos and resource-based. Respondents were asked to rate a number of ways of maintaining an advantage over their rivals for each of the sectors in which they were involved. Overall; technological advantage was given the highest mean rating. Respondents were also asked to rank in order of importance a variety of methods of protecting and/or securing technological knowledge, including cost of imitation for competitors, secrecy, patents, brand-name recognition, know-how advantages and economies of scale, both at present and ten years ago. Patents were ranked first by pharmaceuticals and other chemicals, now and ten years ago. Furthermore, pharmaceuticals ranked patents significantly higher than any other sector, both now and ten years ago.

In terms of the methods of obtaining technical information, 50% of pharmaceutical cases and 40% of other chemicals gave published patent specifications the highest ratings. Other sectors gave much lower importance to published patent specifications as a source of information. Across the entire sample, the most important source of technical information was in-house R&D and in-house production.

Nelson (1990) also presents the results of some survey information he collected with several colleagues. He distinguishes four broad classes of means through which firms can appropriate returns to their inventions: the patent system, secrecy, advantages associated with lead time and complementary investments such as sales and service efforts. In most industries, lead time (and such associated potential advantages as ability to move down the learning curve), and establishing an effective sales and service effort, were rated as the most effective means. Included here were such industries as semi-conductors, computers, telecommunications and aircraft. In some of these industries, patents were also rated as reasonably effective, in others not. There were several industries in which patents were rated as quite effective. In some of these, principally those producing complex chemical products, it would appear that without patent protection, R&D would not pay. Product patents for drugs were regarded as strictly more effective than any other means of appropriation. It has been noted that the importance of patent protection may be understated in these types of surveys by a focus on large firms. Patent protection may be more important for small, start-up ventures that lack complementary assets, since they need to market the technology in order to exploit it, and patents assist them in marketing the underlying technology (Levin, Klevorick, Nelson and Winter, 1987). In most industries, the means of monitoring product innovations judged most effective was either doing independent R&D (presumably while attending to clues about what one's competitors are doing) or reverse engineering.

Sharma (1993) also concludes that R&D executives place the greatest stress on product patent protection in the pharmaceutical industry, agricultural chemicals (for example, pesticides and herbicides, subject to analogous federal testing regulations) and industrial organic chemicals. This is consistent with findings of Mansfield, Schwartz and Wagner (1981) that patents raise imitation costs most prominently in the case of drugs and chemicals. Several studies of the pharmaceutical industry shed some light on why patenting seems especially important in this sector. For example, Grabowski and Vernon (1982) note that there is little to stop rival firms from producing chemical compounds on similar terms as the innovator in the absence of legal barriers such as those afforded by the patent system. The authors estimate that an average product life of 12 to 19 years is needed by firms to cover R&D costs and provide a real rate of return on investment of 8 to 10 percent. They note that average effective patent life is considerably less than this estimate.[29]

Langford and Blaker (1991) identify distinctions between product and process patents. Specifically, patents for new pharmaceutical products are typically considered more effective than those for processes, and secrecy is considered less effective in protecting products than processes. The appropriability of returns for inventors is dependent on the scope and duration of patents.

[29] The implication of this observation is that R&D activity will contract in the industry until the private rate-of-return increases to the cost-of-capital. This does not imply the extinction of R&D in the industry.

While the effective period for market exclusivity of an innovative pharmaceutical is shortened due to regulatory delays, a firm's competitive position may also be increased due to the advantages inherent in being a patent-holding pioneering brand. Investments in the trademark of a patented medicine are made during a period of market exclusivity which may be exploited after patent expiry through the continued promotion of brand names.

5.2.3 Distribution of Economic Surplus Among Inventors and Others

The distribution of the gains from innovation between the inventor (or patentee) and the rest of society obviously varies from case to case. In broad terms, the distribution is reflected in differences between private and social rates of return to innovation. *Ex post* social rates of return usually are substantially higher than *ex post* private rates of return, thereby suggesting that users of innovations and imitators capture the largest share of the relevant commercial benefits. Moreover, the overall social rates of return are quite large, on average. For example, the majority of estimated social rates of return to agricultural innovations exceed 35 percent per annum, while returns on public research expenditures in forestry can range above 100 percent annually (see Hyde, Newman and Sheldon, 1992).

Some additional evidence on the distribution of gains from patenting is provided by evidence on company licensing and royalty fees earned by patentees compared to the estimated cost savings associated with the licensed inventions. On average, the patentee is likely to be able to appropriate something less than one-third of the cost reduction resulting from her invention (McFetridge and Rafiquzzaman, 1986). In short, notwithstanding the existence of patent protection, it would appear that the patentee is typically able to appropriate a relatively small portion of the economic surplus generated by her invention.

5.2.4 Distribution of Surplus Between Nationals and Non-Nationals

The distribution of surplus by nationality will depend in part upon the distribution across participants, as described in the preceding section, as well as the nationalities of those participants. The likelihood that the participants will be domestic residents rather than foreigners will largely be influenced by the size of the domestic economy in question, as well as by the specialization of economic activity within that country. In fact, Berkowitz and Kotowitz (1982) show that a country with less than about 90% of world production and consumption of the goods produced by the industry which uses a process innovation will find it optimal to maintain no patent system, *ceteris paribus*. In effect, it almost always pays for an individual country to refuse to participate in the world patenting system if other countries continue to participate.[30] This is even more true for a

[30] McFetridge and Rafiquzzaman (1986), estimate a lower but still relatively large (62%) as the threshold for adopting a "free-riding" posture towards patent protection. Their lower threshold is due to their assumption that post-patent competition dissipates some of the potential royalties that would be earned by patentees.

small country such as Canada which will likely account for a small share of total patenting in any scientific activity.

In fact, as suggested in an earlier section and as will be elaborated upon below, large countries have an incentive to "discipline" countries that do not provide intellectual property protection of a "minimally acceptable" standard. Hence, free-riding on the patent protection of other countries may not be easy or even feasible in the long-run. Moreover, in some activities even a small country may be a relatively large participant in the marketplace as a producer and/or consumer. In such cases, extending patent protection to those activities may be economically beneficial, especially if patent protection is already granted to a wide range of other activities. For Canada, forestry biotechnology comes to mind as a possible example in this regard.

5.2.5 Pre and Post-Patent Competition

A good deal has been written about whether and how the patent system encourages or discourages "wasteful" competition in the pre and post-patent stages (see Kitch, 1977; Gilbert and Newbery, 1982; and Waterson, 1990). The basic theoretical conclusions are that strengthening the patent regime will encourage pre-patent competition, although it might discourage post-patent competition. Conversely, weakening patent protection might discourage pre-patent competition while encouraging post-patent competition. In effect, there may be a tradeoff between pre and post-patent competition. One's position on the nature of this tradeoff is conditioned, in part, by one's perceptions of the technological change process.

As suggested earlier, improvements to basic patents are important sources of technological change. If one believes that control of technological developments by a small number of firms is desirable, one might favour a patent regime that discouraged post-patent competition. This might be especially true if pre-patent competition was limited in scope by a concentration of requisite scientific skills among a small number of firms. In this case, duplicative waste through excessive competition in the pre-patent stage is unlikely. The converse set of conclusions might be drawn if technological change proceeds faster with greater competition in the post-patent stage and if required expertise to engage in pre-patent competition is broadly dispersed among firms.

The factors conditioning the likelihood and optimality of pre and post-patent competition are ultimately empirical in nature. In this regard, McFetridge and Rafiquzzaman (1986) discuss surveys of innovative firms which suggest that there was relatively little parallel research (to their own) of which the surveyed firms were aware. This suggests that pre-patent competition may have been quite limited in scope; however, McFetridge and Rafiquzzaman also note that the limited amount of parallel research might reflect successful pre-emption on the part of specific firms. In effect, limited parallel research by itself does not indicate that conditions for pre-patent competition don't exist.

Nelson (1990) argues that historically the science needed to advance technology was the "packed down" science of textbooks and handbooks, and mostly what the industrial scientist learned in school, rather than "frontier" science. By itself, this observation suggests that conditions are conducive for pre-patent competition in many industries; however, experiential learning might be a factor limiting competition. Nelson does note that technologies relating to chemistry and electronics have been exceptions, with technical advance often drawing on or being intertwined with frontier sciences. Moreover, he claims that many technologies are closer to science than they used to be. At the same time, long hands-on experience in firms has become less important as a privileged vehicle to gain generic understanding. Rather, firms will increasingly need to be engaged in applied research to be successful in pre-patent competition. Interestingly, Nelson sees this trend as augmenting rather than diminishing the potential for pre-patent competition, since generic technological knowledge will be less of a monopoly of those firms with long experience in the specific technical area. Mowery and Rosenberg tend to support Nelson's position in concluding that following the early stages of industrial research, the growth of unpatented firm-specific bodies of knowledge became the major barrier to entry for new competitors (Mowery and Rosenberg, 1990).

The degree of post-patent competition will be a function of a number of factors including ease of entry into the relevant activity, the willingness and ability of firms to engage in cross-licensing agreements and so forth. These factors will obviously vary from case-to-case; however, large differences between private and social rates of return to successful innovations suggest that there is ordinarily substantial competition at the post-patent stage such that a substantial share of the commercial benefits of new technology are passed-on to users of the innovations. Anecdotal evidence that "fast-followers" are often more commercially successful than innovators is also consistent with a perspective that there is ordinarily strong patenting competition in the post-patent stage and that such competition is socially beneficial.

In summary, a plausible argument can be made that both the pre and post-patenting regimes are characterized by significant potential and actual competition. In this context, there are increased risks associated with strengthening patent protection, especially by broadening the scope of protection. For one thing, stronger patent protection will encourage even more pre-patent competition with attendant risks of competitive duplication. For a second, it will likely constrain post-patent competition, and competition in this stage is likely to have significant net social benefits.

5.2.6 Reactions of Foreign Governments

A review of government interactions surrounding intellectual property protection is well beyond the scope of this study. Suffice to say that the United States government has been very aggressive in demanding relatively strong levels of intellectual property protection among its trading partners. This has led to conflicts with the Canadian government in specific cases. One notable case involved Canada's relatively liberal policies towards generic pharmaceutical production. The movement away from this liberal policy arguably reflected to some extent, the pressure exerted by the U.S. government.

It can be safely concluded that to the extent that Canadian policies towards intellectual property protection in the biotechnology area substantially depart from U.S. policy interests, in particular if they are significantly "weaker", bilateral conflicts will arise.[31] Moreover, in the absence of U.S. support, Canada's position with respect to other countries and regions including Japan and the EC will be relatively weak. The implication is that political considerations may be as relevant as economic considerations in this area.

5.3 Applications of Economic Considerations to Biotechnology Patenting

In this section, we assess broad economic criteria influencing patent policy against the background of the biotechnology industry with particular emphasis on forestry biotechnology. The earlier review of general evidence surrounding the patenting process led to a number of broad conclusions. One is that the experience of the pharmaceutical and industrial chemical sectors has traditionally been different from the experiences of other industrial sectors. In particular, patent protection is seen as being a much more important conditioner of profitability in pharmaceuticals and industrial chemicals than in other industrial sectors. Hence, an issue raised in this context is whether the invention process in biotechnology is more akin to pharmaceuticals and industrial chemicals than to other sectors. In particular, are the pre and post-patent competitive processes similar? Are the outputs of the R&D processes similar, i.e., codifiable elements readily capable of being analyzed and duplicated, or are non-patent forms of protection more viable in the biotechnology area? To the extent that there are strong similarities between biotechnology and pharmaceuticals and chemicals in these dimensions, a similar patent protection regime may be appropriate, *ceteris paribus*.

A second broad conclusion is that encouraging post-patent competition is generally preferable to discouraging such competition, especially when there is a relatively diverse range of potential applications for the relevant technologies and when the potential commercial applications are broad-based and difficult to predict *ex ante*. This suggests that the scope of patent protection be relatively limited. On the other hand, if the technology being developed is specific to narrowly defined applications that are readily identifiable at the outset of the innovation process, a broader scope of patent protection might be appropriate to discourage competitive duplication of innovation in the post-patent period, especially if inter-firm licensing is problematical for one reason or another. The likely natures of pre and post-patent competition in the biotechnology area are therefore potentially relevant.

---

[31] As noted earlier, bilateral conflicts are more likely when one of the partners sees its commercial interests directly threatened (or targetted) by the other's actions. In this context, U.S. authorities might not protest strongly against Canada's lack of patent protection on forest trees, *per se*, if there was a relatively small overlap of potential competition in specific tree species, and if innovations are relatively species-specific. Softwood lumber in the Pacific Northwest presents the most obvious overlap; however, restrictions on cutting in the U.S. have made this a less important area of competition between Canada and the U.S. than in the past.

A third broad conclusion is that the social rate of return to innovation generally exceeds the private rate of return by a significant margin. The implication is that users of innovations are typically much larger beneficiaries than the inventors or innovators.[32] For a small country such as Canada, where typically the relative population of "users" will be large relative to the relative population of inventors, there is an even greater-than-average incentive to "free-ride", i.e., to have a weak patent protection regime to encourage a faster rate of adoption of inventions by domestic users. However, there are several possible caveats to this conclusion: (i) the ultimate beneficiaries of the inventions may be foreign consumers to the extent that any cost savings or other benefits are passed from domestic producers to foreign consumers in export markets; (ii) in specific segments of an industry, domestic producers may be the most likely inventors and innovators, notwithstanding that the country as a whole is small; (iii) there may be strong technological spillovers from the sector in question to other sectors. For example, R&D performed in sector A may contribute to higher productivity in performing R&D in sectors B and C; (iv) weak intellectual property protection may trigger even more costly retaliation from the country's trading partners. All of those factors will also be considered in the context of the biotechnology sector.

5.3.1 Rates-of-Return and the Importance of Patenting for Biotechnology

Available evidence suggests that *ex ante* rates-of-return to R&D in the biotechnology activity are becoming more relevant as determinants of R&D in this sector given that such R&D is increasingly driven by commercial imperatives. In this regard, there is a clear trend towards commercialization of R&D incentives owing to several factors: (1) a decrease in the relative amount of funding provided by the government; (2) growing linkages between universities and government research labs and private sector companies; (3) advancement of fundamental science to the stage where commercial applications are increasingly feasible.[33]

There is also a suggestion in recent developments that required rates-of-return to biotechnology R&D will approximate those characterizing the pharmaceutical and chemicals sectors. The primary basis for this speculation is the observation that an increasing number of large chemical and pharmaceutical companies are establishing significant in-house capabilities in the biotechnology area. For these companies, the opportunity cost of doing biotechnology R&D is the expected return in other related scientific activities.

One point that might be raised in this regard is that developments in forestry biotechnology applications lag behind those in medical applications, and even in agricultural applications. Specifically, commercial activity in forestry biotechnology is much more limited than in medical or agricultural biotechnology. Government and other publicly funded institutions continue to be the main players in biotechnology applications outside the medical and pharmaceutical products sectors. Moreover, the outlook is that this will continue to be true for the foreseeable future in selection and improvement of forest tree species. One reason is that time will remain a major

---

[32] This seems to be particularly true for forest products. See Hyde, Newman and Seldon (1992).

[33] See Section 3.

constraint in the progress of tree improvement programs. The long breeding and testing processes which are required for commercial applications make tree improvement more difficult, costly and uncertain compared to the improvement of many agricultural crops.[34] Similarly, the high uncertainties involved in the research and development process reduce the commercialization potential of activity in this area, particularly since lower risk, more "conventional" breeding and improvement techniques are available.

Another factor which has been found to discourage commercial R&D by private producers, especially in the plywood, sawmill and pulpmill areas, is the competitive level of production and rapid transfer of benefits to consumers.[35] To some extent, vertical integration in the industry mitigates some of this concern; however, the relatively atomistic organization of the wood products segment of the industry suggests that producers will have relatively short time horizons and limited amounts of capital to perform long-term R&D projects.

The outlook is slightly different for biopesticides. Genetic engineering is likely to expand the range of microorganisms that can be used as delivery systems for biotoxins. Great interest is now shown by researchers in the introduction of viruses as means of delivering toxins to insects. The use of larger organisms as predators to control insect population is also being experimented with. The use of multicellular organisms for this purpose, however, is limited by both economic and ecological concerns.

The commercial outlook is more immediate yet in the case of applications of biotechnology to improving production processes in the pulp and paper industry. While this interest is largely driven by environmental regulations imposed by governments, the likelihood is that such interest will continue.

In summary, while there are similarities between biotechnology and pharmaceuticals which suggest that a similar patent regime may be appropriate, all other things constant, there are distinctive characteristics of forestry biotechnology which suggest that, in the short-run at least, the risks of erring on the side of weak patent protection are relatively low. As noted above, the present values of expected profits from inventions with long terms to payoff are relatively low, so the prospect of private funding is not significant, in any case. Patent protection with normal terms to maturity will not change this imperative. Moreover, patents may not be as important in the protection of intellectual property as they are in other biotechnology applications. Relevant notions here include the following observations: (i) while the basic research elements of the application of biotechnology to forestry are well known, the "art" of processing and preparation of products is proprietary and is often protectable by secrecy; (ii) many of the research results (especially in the field of somatic seeds) do not have a universal application and often require a close relationship between the producers of biotechnology and the users (e.g., forest products companies, nurseries,

---

34 This assertion is further supported by the observation that R&D payoffs in timber management activities have traditionally been relatively low. See Hyde, Newman and Seldon (1992).

35 While concentration in the domestic pulp and paper sector is high relative to the logging and plywood sectors, it is low in an international context, and pulp and paper are internationally traded products.

etc.). This also implies lower risk that the technology developed can be readily appropriated for use by other firms.

This conclusion may be less appropriate in the case of biopesticides than in the cases of improved seeds and bioprocessing.[36] The market for biopesticides is well developed with a significant presence of large diversified companies that produce both chemical and biological pesticides for forestry and agriculture. In this market, the role of governments in funding and producing applied research is rather minor and commercial imperatives are fairly immediate. Hence, in the case of biopesticides in particular, other factors conditioning the welfare impacts of patenting may be of particular relevance.

5.3.2 Participants in the Relevant Markets

Identification of participants in the production and use of forestry biotechnology is useful in two dimensions. One is that it assists in identifying the likely distribution of the welfare consequences. Another is that it provides some insights into the nature of pre and post-patent competition in the activity.

5.3.2.1 Seedlings

In Canada, there is relatively high provincial government ownership of seedling production. Moreover, relatively little of harvested forest lands in Canada are directly seeded. Specifically, most are left largely for natural regeneration. It can be concluded that the commercial implications of biotechnology developments in this area of application are likely to be small and, relatedly both pre and post-patent competition is likely to be limited.

5.3.2.2 Processes to Improve Trees

Roughly half of seed orchards are Crown facilities and half are private, with a strong trend toward the latter. At present, the annual number of genetically improved seedlings planted in B.C. is roughly 25 million (or only about 10% of the total number of seedlings planted in B.C. annually).

---

[36] As an illustration of this point, between 1989-92, 1589 biotechnology applications under the IPC classes were laid open in Canada, Industry Canada was able to summarize the claims of 646 laid open applications. Of these, only 27 represented claims directed to plants or seeds. In a search of international data base of patents (Derwert WPIDS), we have identified 381 patents relating to Bt based biopesticides of which 53 were granted or published in Canada (all to foreign companies). Only 2 patents for multicellular organisms intended to be used as forest and agricultural pest control agents were found (Japanese patents). Both patents were issued for parasitic nematodes to Oji Paper of Japan. We have found 25 patents related to trees and tree seeds. Most patents related to processes for developing somatic tree seeds. Three patents were issued for commercial forest trees resistant to some insects. Nine were issued for ornamental and fruit tree varieties. In another search we found a patent issued to B.C. Research for a process to develop somatic tree seeds.

While this percentage is likely to increase in the future, the conclusion is again that the commercial implications of scientific developments in this area are limited over the near term.

Identification of institutions involved in seed forest biotechnology research points to limited pre and post-patent competitors, as well as the prominence of government funded R&D. For example, in somatic embryogenesis there is only one major commercial player in Canada (B.C. Research). In fact, B.C. Research is the only "player" in the world for northern conifers. Forest companies have funded R&D through B.C. Research as well.

There are a number of non-commercial research centres in Canada that do considerable research in tree breeding technologies. They have agreed to collaborate with B.C. Research in conifer biotechnology. These centres are funded at the federal level. In the United States, there are a number of institutions doing work on somatic embryogenesis, all on Douglas fir and Loblolly pine. These include the U.S.D.A. Forest Services, several universities and a few firms in private industry. Internationally, the only large scale research in somatic technology is taking place in New Zealand on Clonal Radiata pine plantations.

In short, research on somatic seeds is limited at present to a few organizations that specialize in regionally specific species. An implication is that pre-patent competition may be limited. Furthermore, at least in this area of research for the foreseeable future, patent protection in any country is likely to protect the intellectual property of local R&D performers.

The market for biopesticides for forestry applications is highly concentrated. The four largest companies supplying the market account for 92% of the global production of B.t. products. R&D is done by these large multinationals, new biotechnology companies and large agrochemical companies. There are no significant Canadian firms in the biopesticide market. In fact, most of the activities in this area focus on pesticides for agriculture rather than on pesticides for the control of forest pests.

One of the largest groups in the world doing research on bioherbicides applied to forestry is the Canadian Forest Service's Pacific Forestry Centre. The research done at the PFC is mostly targeted at biological control of insects. The commercial prospects for biopesticides tend to be brighter than those for bioherbicides. This is because bioherbicides tend to be relatively expensive compared to chemical herbicides.

Aside from the PFC, the Canadian Forest Service also has facilities doing research in biopesticides in other parts of the country. The National Research Council of Canada is also a noted player in the area of biotechnology in pest control. In the U.S., only one of the U.S. Forest Service laboratories is experimenting with B.t. However, their focus is on naturally occurring bacteria and not on engineered organisms. Applied research on biopesticides in universities is usually conducted cooperatively with industry. Basic research on the mechanisms involved in controlling pest populations and the development of new strategies for pest controls is conducted in Canada and U.S. universities.

In summary, there is a growing amount of commercial competition in biopesticides; however, Canadian commercial interests are not strongly represented in this sector of the industry.[37] Indeed, as in other segments of the industry, government agencies and publicly funded departments tend to dominate Canadian research and development. Moreover, the activity focus of the research and development undertaken (to date) tends to be fairly specific. An implication is that pre-patent competition may not be strongly influenced by the extent and nature of patent protection. Hence, concerns about strong patent protection encouraging wasteful duplication of pre-patent stage research are not very compelling -- at least at the present time. However, the relevance of patent protection in Canada is moot given the small number of Canadian R&D performers in this area, as well as the dominance of government and publicly funded departments. These latter participants are less likely than private firms to rely upon intellectual property protection as the basis for attracting investment capital.[38]

5.3.3 Participants in the Relevant Markets (Demand Side)

The demand for seeds and seedlings is derived from reforestation decisions. In Canada, governments own about 95% of commercial forest lands and thus control the amount of trees planted. The direct implication is that any "economic rent" to users generated by yield improvements and/or improved marketability of trees tied to seed biotechnology is, in principle, captured by government landowners. The indirect implication is that government can capture the benefits of R&D in its role as landowner. In practice, such rent-capture may be imperfect, either because stumpage fees may not fully reflect profits to private forest products companies, or because some of the developments may be directly beneficial to forest products companies. e.g., improvements which protect forests in the short-run and thus protect harvesting rights.

In Canada, almost 90% of seedlings utilized in reforestation are associated with three species: Jack pine, white spruce and black spruce.[39] To the extent that Canadian forests are especially rich in these species, Canadian forest products companies may be particularly prominent beneficiaries of seedling developments affecting these species, especially since there is virtually no exporting of seedlings. Alternatively, if the benefits are passed through to consumers of the final products made from these species, the extent of exporting versus domestic consumption of final output is relevant in considering distributional effects.

Indeed, the larger share of production of forest products is destined for exports. The demand elasticities that Canada faces for its major commodity exports are inelastic in the short and mid term. Innovations which increase exports are likely to result in price and revenue decreases. While

---

[37] This is underscored by the following observation. Of 24 laid open patent applications in Canada classified as bio-control or bioherbicide, only one inventor was Canadian. (Private correspondence to authors from Industry Canada).

[38] Surveys reported in Heller Consulting (1984) indicate that access to investment capital being contingent on intellectual property protection is probably the strongest reason for biotechnology firms to seek patent protection.

[39] See Table 1.

producers (domestic) surpluses may decline the benefits to consumers will mainly accrue to foreign consumers.[40] In the long run one must consider the effects of higher prices on the introduction of substitutes. Canada with a large inventory of forest resources has a strategic interest in preventing price ranges that induce permanent substitution. Indeed environmental regulations in Canada and the U.S. have already pushed lumber prices to levels which may provide incentives for builders to change construction technologies and substitute for some of the wood products used in construction. Higher fibre prices combined with environmental regulation and public demand for greener products, have led to a higher use of recycled fibre. Thus innovation which increases forest productivity (e.g., improved trees with higher growth rates) should be encouraged if a long time horizon is considered for social welfare calculation. Unfortunately because of the existing system of incentives rooted in the dominant tenure systems and the public ownership of the resource IP protection policies are not likely to stimulate Canadian private sector innovations that lead to improved forest productivity.[41] Innovations that are targeted to short term cost cutting in forestry and processing, insurance and product differentiation are likely to result in improved social welfare. Such innovations are likely to be stimulated by higher level of IP protection, though the specificity of innovations given differences in the resource endowment between regions may make such protection less necessary.

Unlike seedlings, there is a fairly active trade in seeds, especially exports from Canada and the U.S. to Europe and Asia. Canadian exports grew to almost $4.5 million in 1990 encompassing 11 species, with Douglas fir, Sitka spruce and to a lesser extent Lodgepole pine making up the bulk of trade. In the U.S., while there are some exports of seeds from the Pacific Northwest, the largest exporter over the past decade has been the U.S. South. Exports from this area, primarily to China, have primarily encompassed Loblolly and Slash pines. A possible inference one might draw is that Canadian innovations in the seed area may not compete significantly with U.S. innovations given different areas of specialization. As a result, competition between the two countries in seed export markets could be limited which makes it more likely that commercial benefits will be captured by seed producers rather than being passed on to consumers.

Canadian demand for biopesticides and bioherbicides is small relative to total global demand. However, microbial insecticides tend to be highly target specific, limiting single applications to a single pest. An implication is that the benefits of individual innovations may be specific to given applications. Hence, Canadian users may be disproportionate beneficiaries of innovations targeted at species especially well-represented in Canada, notwithstanding that Canadian demand is relatively small in the overall world market.

The extent to which the benefits of biotechnology innovations in the insecticide area are captured by consumers is, in part, a function of competition among producers of biopesticides and bioherbicides and chemical pesticides. At first glance, it would seem that there is substantial

---

40 Producers' surpluses may not decline if cost decreases offset price effects to yield higher net revenues.

41 Presumably governments as the owner of the resource is motivated to invest in R&D (but R&D expenditures on forests by provincial governments do not reflect this motivation). The issue of whether private R&D labs are likely to be more productive than government R&D labs is beyond the scope of this study. We are aware of no studies of this issue for the forestry sector.

competition between these two broad groups of producers. At a closer glance, the degree of substitutability is limited in the pesticide area by increasing concerns about environmental hazards raised by chemical pesticides. Moreover, the development of biopesticides is cheaper than the development of comparable chemical pesticides. On the other hand, bioherbicides are substantially more expensive than chemical herbicides.

As an overall summary, we can conclude that, for the foreseeable future at least, participants on the "supply side" of the forestry biotechnology market (defined to encompass biopesticides and herbicides) will tend to be relatively specialized in terms of their innovation activities. Moreover, they seem to be focusing on problems particularly relevant to local users, so that the benefits of their innovation activities tend to be concentrated within specific segments of the industry. All of this suggests that innovators in this area may be able to internalize more of the benefits than is true in the case of innovation, more generally.[42] In addition, those benefits not captured by local producers may be captured by local users, and will be retained by local users to the extent that the latter enjoy market power in the downstream markets in which they operate. As such, Canada may not have strong reasons to rely upon patent protection as a vehicle to promote forestry biotechnology.

5.3.4 Some Additional Evidence on the Distribution of Benefits and Costs of Patent Protection

To the extent that benefits of biotechnology research are passed through to forest products companies, the identity of the companies and the structure of "downstream" markets will also condition the distribution of the associated benefits and costs.

The main characteristics of downstream markets, especially with reference to Canada's participation in those markets, might be summarized as follows:

(i) Canada is the world's major producer of softwood lumber. The U.S. and the former Soviet Union are the largest lumber producing countries.

(ii) Canada is the dominant exporter of softwood lumber (about 50 percent of world exports in 1991).

(iii) Canada is a major exporter of wood pulp and newsprint accounting for over 56 percent of all newsprint exports in 1991.

(iv) Canada was the world's largest producer of newsprint and the second largest producer of wood pulp.

---

42 To be sure, species in Canada compete with species in the Soviet Union, Scandinavia and the U.S. Hence, the benefits of "unprotected" technology might be appropriated by rivals. Moreover, a generic technology that can benefit a wide range of species might also be at risk through appropriation by rivals. Nevertheless, trade secrets and plant breeders' rights can be relatively effective forms of intellectual property protection. See Heller Consulting Inc. (1994, p. 203).

(v) The U.S. is the largest importer of Canadian lumber and newsprint, however, it has a more dominant import position in the newsprint sector. Canadian exports are somewhat more diversified by country in the lumber and wood pulp sectors.

(vi) Canada is a relatively and absolutely small producer of paper and paperboard excluding newsprint.

(vii) Canada is a relatively and absolutely small consumer of forest products with the possible exception of wood pulp.

These observations suggest several inferences about the impacts of intellectual property protection in the forestry sector. One is that Canadian producers as a whole are not pure "price takers" in the softwood lumber, wood pulp and newsprint sectors. This suggests, in turn, that cost reductions will not necessarily be passed completely through to consumers of these products, the bulk of whom are non-Canadians. Equivalently, Canadian producers will be able to sustain higher prices for "improvements" made to these products. Indeed, they may be able to capture the bulk of the monetary value of these improvements in the form of higher prices for particularly differentiated innovations; however, as noted earlier, all broad segments of the industry are relatively competitive. Hence, final consumers will be substantial long-run beneficiaries of competitive innovation in the industry.[43]

At the same time, Canadian producers are price takers in the paper and paperboard sectors (excluding newsprint), given their small share of world output. This, in turn, suggests that the economic benefits of any cost reductions and/or product quality improvements characterizing these sectors are likely to be passed on relatively quickly and substantially to consumers, the bulk of whom are again foreigners. Hence, to the extent that future developments in biotechnology primarily affect the lumber, pulp and newsprint sectors of the industry, Canadian-based producers are in a position to realize significant economic benefits, whereas the benefits captured by Canadian producers are likely to be much more limited if biotechnology developments primarily impact other forestry activities. Our earlier overview of biotechnology activities suggested that the major developments over the long run are likely to affect the "upstream" segment of the industry in terms of increasing harvesting yields and improving species attributes. The implication is that Canada has a relatively strong interest in encouraging innovation in"upstream" sectors of the forestry industry, since it is prospectively a disproportionate beneficiary of innovation in those sectors.

This assessment of the prospective benefits to Canada of biotechnology-based innovations in the industry might be tempered by several developments:

(i) demand for the products of Canadian producers is declining;
(ii) potential entry is growing in sectors where Canadian producers are price takers.

---

43 This presumes that government does not extract all of the benefits in the form of higher royalty fees.

With respect to the second item, Canada is the second largest potential producer of temperate wood products based upon raw forested land. Major areas of the world from which timber exports can increase are South America and Africa; however, these latter regions produce tropical hardwood, and elasticities of substitution between temperate and tropical wood products are relatively low.[44] The major potential source of increased temperate timber production is the former Soviet Union. Given existing political and economic conditions in that country, it is unclear that significant increases in supply would emanate from that country pursuant to price increases for temperate wood products.[45] At the same time, emerging pulp producers in Southern hemispheric countries can compete against Northern hemispheric producers. That is, elasticity of supply is significantly higher in the pulp and newsprint sectors.

With respect to the first item, the dominant customer for Canadian exports of softwood lumber, wood pulp and (especially) newsprint is the U.S. There is no obvious reason to expect this market to "fall away"; however, there is no obvious reason to expect it to grow dramatically either. Environmental concerns in the U.S. are limiting harvesting, especially in the Pacific Northwest, which (by itself) increases demand for Canadian lumber. At the same time, Canadian exports of wood products are under threat from complaints by environmentalists about harvesting practices of Canadian companies. Moreover, traditional lumber products are facing increasing competition from various sources including engineered wood products that use less lumber and non-wood products such as steel. In the pulp and newsprint sectors, a trend towards using recycled newsprint threatens exports of Canadian newsprint made from traditional fibre stock.

There is some indication of increased demand for softwood lumber in emerging Asian economies as countries such as China and South Korea substitute softwood lumber for hardwood. Moreover, a significant move towards using dimension lumber as a building material in South America might significantly expand demand in that area of the world for Canadian lumber exports.

In short, the economics of the "upstream" sector of the industry do not seem poised to change radically over the foreseeable future. On balance, supply pressures may be greater than demand pressures. Specifically, harvesting limitations in Canada may place an increasing premium on improving yields in the forests; however, the economic imperatives to promote this development through biotechnology R&D may be muted by slowing growth in the demand for wood-based products.

5.3.5 Technology and Dynamic Comparative Advantage

It might be suggested that inferring the potential implications of innovation in the forestry sector based upon Canada's existing patterns of production is inappropriate, since technological innovation might be the basis for Canadian producers to diversify into higher value-added products

---

44 *Ibid.*, p. 5.

45 Nor is it clear that the states in the former Soviet Union offer an environment (e.g., secure property rights) that will encourage forestry innovation.

such as specialty papers. Given the more favourable economic outlook for higher value-added products, there would be compelling economic benefits to Canada if innovation created a dynamic comparative advantage for Canada in those sectors of the industry in which it is currently a minor producer.

In fact, it seems unlikely that Canada's weak competitive position in higher value-added sectors will be significantly mitigated by developments in forestry biotechnology. For one thing, successful innovation generally requires close and strong linkages between innovators and the potential users of the potential innovations. Given Canada's weak representation in the higher value-added segments of the industry, Canada suffers from strong locational disadvantages in undertaking the relevant R&D. Moreover, the "branding" of consumer-oriented paper products and other initiatives to create consumer brand loyalty create formidable barriers to entry for new producers, even if the latter are relatively quick to develop and exploit new technology.

In summary, it seems most reasonable to focus on the implications of forestry biotechnology for the timber, pulp and newsprint sectors when seeking to identify the potential benefits to Canada of promoting biotechnology innovations. The prominent market positions of Canadian producers in these sectors suggests that significant potential benefits exist.

5.3.6 Application of Economic Criteria: Overall Summary

Given the limited and eclectic evidence surrounding the forestry biotechnology process, it is very difficult to assess the evidence in a way that closely matches the "template" created in Figure 4. Perhaps of most immediate relevance is the observation that Canadian R&D tends to be concentrated among non-commercial organizations that are currently government funded. Were this model to continue, along with the relatively specialized nature of the research which renders it especially appropriate for exploitation by Canadian producers, economic concerns about a "too weak" patent regime would seem misplaced. Specifically, government research institutions could presumably pass their results on to domestic firms at little or no cost and the latter could "internalize" the knowledge for commercial exploitation. Through its ownership of public lands, the government is in a position to capture much of the commercial benefits of its R&D through royalty and stumpage fee arrangements.

Government research organizations and universities are facing increasing commercial imperatives. That is, they are increasingly expected to "pay their way", either by earning royalties and fees directly or by attracting research funding from the private sector. In the longer-run, as in other sectors of the biotechnology industry, small for-profit firms might be expected to spin-off from the large non-profit organizations currently dominating forestry biotechnology in Canada. Patent protection will be more important for these small spinoffs, particularly as an instrument for encouraging capital investment by larger firms. As noted earlier, it is unclear that innovation will be accelerated with more R&D being done by small, private firms; however, for new tree species (in any case) the government is the ultimate clientele for the research. As such, arrangements in which small firms perform R&D under contract to government agencies might be a way to improve the efficiency of R&D performance in Canada, on the margin. In this case patent protection for new or improved tree species will be irrelevant, since the commercial interest of the private firms is in performing R&D and not in producing forest products.[46]

With respect to other products, such as biopesticides, the main markets for the products will be outside-of-Canada. In this context, patent protection in Canada is of minimal relevance compared to patent protection in the U.S., Europe and Japan.[47] Strengthening the patent regime in Canada might therefore be justifiable primarily as a means to an end; i.e., stronger protection of Canadian intellectual property in other countries.

In summary, purely economic determinants provide a relatively weak case for a strong domestic patent protection regime for forestry biotechnology. More specifically, they suggest that incentives to perform forestry R&D are influenced more strongly by ownership arrangements in the industry and by patent regimes elsewhere than by the patent regime in Canada. On the margin, some additional R&D in activities such as biopesticides might be stimulated by stronger domestic patent protection; however, offsetting this consideration are the higher prices for patented products (by foreign firms) Canadians would pay for these products. Since the bulk of biotechnology R&D in these activities is done by foreign firms, the "balance of trade" for Canada is likely to be worsened by stronger intellectual property protection.

[46] To the extent that the firms performing R&D under contract own the resulting IP, they have a stronger interest in the underlying IP protection regime. If the government buys R&D services from private firms, in principle, it pays less (directly) by allowing the contractee to own the resulting technology. Alternatively, given weak IP protection, the government presumably would pay more directly when purchasing R&D services. Thus, the firm should be indifferent as to how it is paid.

[47] This point is made strongly in Heller Consulting Inc. (1994).

6.0 THE SPECIFIC DESIGN OF THE LEGAL AND INSTITUTIONAL FRAMEWORK FOR IP PROTECTION OF MULTICELLULAR (HIGHER ORDER) ORGANISMS

The economic analysis in Section 4.0 presented a weak case for strong IP protection of innovations involving multicellular organisms. In this section we broaden the scope of the analysis to include non-economic considerations and arrive at specific recommendations with respect to the desirable IP protection regime. The non-economic issues involved are diverse. They include: metaphysical and theological arguments, concerns for the suffering of animals, debates about the rights of humans to control animal life, environmental risks, concerns about international equity and domestic distributive impacts and their political consequences, legal arguments and precedents, international obligations and practical implementation problems. We first review some of the objections to the patenting of higher order organisms. We conclude that while some of the objections can best be dealt with outside the IP protection policy domain, others can be dealt with by selecting appropriate legal instruments of protection. We then explore the design characteristics of alternative IP protection mechanisms. The choice of a mechanism must comply with the existing body of law, the evolving legal doctrines and Canada's international obligations. Review of these as well as microeconomic factors associated with obtaining and enforcing protection lead to a choice of an intermediate level of protection such as Plant Variety Protection Mechanisms.

6.1 Other Considerations

If the major reason to have IP protection is the net benefits to society that accrue from such a system, one could wonder whether classes of innovations that may be harmful to society should not be discouraged by denying them IP protection. Indeed, many of the arguments against patenting living organisms are based on the perceived harm that the provision of IP protection may cause or the harm that the particular class of innovations may inflict on society. For example, "ability to prevent others from using patented plant varieties for development of new ones has been cited as potentially leading to additional, and unacceptable, narrowing of an already narrow germplasm base" (Duvick, 1993). It is also argued that since patenting requires an invention of an homogeneous identifiable stable product it will lead to preferences by researchers for working with stable genetic materials, thus leading to a reduction in variety and therefore to a lower biodiversity.[48]

Cost-benefit analysis of IP protection schemes must of course consider the relevant referent system for social welfare calculations. If the unit of analysis is the country, a possibility is that a country with a low potential for innovation in a particular field (e.g., a small developing country) may want to prohibit strong IP protection so as to "free ride", enjoying the products of invention activities stimulated in other countries by strong IP protection regimes. It is not surprising, therefore, that large technologically advanced countries press, in bilateral and multilateral

48 But on the other hand, increases in investments in differentiated products may promote diversity.

negotiations for strong IP protection in all countries. (We shall discuss the international aspects of patenting later).

6.1.1 Equity and Distributive Considerations

Objections to strong IP protection may arise from a wide range of both economic and non-economic perspectives. There are other objections to patenting based on consideration of international equity. "The patenting of useful genes found in nature is particularly controversial. For farmers and consumers in the developing world it could mean paying royalties on products that are based on their own biological resources and knowledge." (FAO, 1993).

Arguments for maintaining national competitiveness in international markets or for attracting innovative firms are often used to support strong IP protection policies in many situations where, in the absence of strong IP protection elsewhere, the country would have been better off not to offer such protection. Objection to patenting of some types of innovation may stem from distributive arguments (and their political implications). Thus, for example, strong IP protection in domains related to agriculture often encounter significant resistance when they are perceived to affect farming income (this irrespective of whether the IP protection generates net social benefits to the country as a whole and subsidies could compensate the farmers for higher costs of inputs).

6.1.2 Theological Concerns

Arguments against patenting transgenic animals are also raised on the basis of metaphysical and theological concerns, including arguments that patenting promotes a materialistic conception of life and raises issues of the sanctity of human worth and the integrity of species (OTA, April 1989). Similarly, issues of animal suffering and inappropriate control over animal life are often raised by environmental and animal rights NGOs.

6.1.3 Transactions Costs

Objections to certain types of IP protection may also be raised on practical grounds of implementation difficulties or the high transaction costs involved. Biotechnology, for example, presents a unique problem since, at the current state of the art, words alone may not be able to describe the invention sufficiently to enable others to reproduce and use it. A deposit of materials is often necessary as part of the description of the innovation. The patenting of animals may require the deposit of a sample of living animals which may be prohibitively expensive, encounter public objections and may be technically infeasible, especially when long periods of deposit are required. As technology advances, some of these objections may be eliminated. Thus, for example, it may be possible and practical in the future to use frozen animal embryos that could be recovered.

Finally, there are some arguments against IP protection which are motivated by a variety of public policy concerns not necessarily directly relevant to the question of IP. OTA (April 1989, p. 3) observes: "One inherent difficulty in examining the patenting of living organisms is determining which arguments raised are novel and directly related to patent issues, as opposed to questions that would exist independent of patent consideration".

6.1.4 Environmental Considerations

Some opponents of patenting living organisms argued, for example, that stronger IP protection will lead to innovations and practices which may be harmful to the environment, and that environmental protection policies are not well developed to deal with such innovations. By limiting property rights they anticipate a slower innovation process and, consequently, a smaller probability of environmental problems. Using IP policies instead of direct environmental regulation is both an ineffective and inefficient way of protecting the environment. There is no guarantee that the fewer innovations which occur will be less harmful to the environment. Indeed, in the absence of stronger IP protection, innovators may be more secretive. Information about innovations and their consequences may not be available to the public and not trigger efforts to protect it. Furthermore, slower flows of innovations may prevent the public from enjoying their benefits, including perhaps the benefits of innovations which may offer more effective protection to the environment.

6.2 IP Protection Mechanisms: Design Characteristics and Attributes

IP protection mechanisms vary in terms of the criteria which must be met to obtain them and the length, breadth and scope of their protection. In this section we focus specifically on some of the major issues encountered in designing IP protection policies for innovations involving plants and animals.

The continuum of protection mechanisms that can be offered typically involves trade-offs between the degree of protection and the difficulty of meeting the criteria required to obtain the protection. In the absence of IP protection, innovators have incentives to keep their innovations secret so as to be able to appropriate their benefits. They are typically aided by trade secret protection laws. These laws generally cover private information used in trade or business that is maintained secret by its owner and provides a competitive business advantage over those not having the information. "Affirmative steps must be taken by an employer to keep information secret (e.g., by limiting access or by contract) so that the secret is disclosed in confidence only to those having a reasonable need to know (e.g., employees). Once information becomes publicly known it loses its status as trade secret" (OTA, April, 1989).

The duty to protect the information is thus the responsibility of the owner. It is an easier task when the protection of secrecy of new processes is at stake but much more difficult when products are involved. This is especially the case with many biotechnological products that are easily duplicated and are grown in the open environment (e.g., new types of plants can be often reproduced using a cutting). Not only is disclosure not encouraged by trade secret protection but the owner of an innovation must actively prevent its disclosure. There are no strict criteria for information to be a trade secret except that it is not public information and that reasonable measures were taken to keep it private. There are no bounds on its duration, breadth or scope. There is no protection, however, from the risk that others will discover the innovation through legal means (e.g., independent research) and use it. On the other end of the continuum of IP protection mechanisms are utility patents. Patents exclude others from making use or selling the innovation. They do not confer necessarily rights to use or sell the innovation. Such rights are typically regulated by other laws.

"It is a universal characteristic of patent law that among the requirements for the patentability of any invention there are four which have prominent importance. Three of these relate to the subject matter which the research worker is seeking to protect i.e. as defined in the claims of the patent application; it must be new, inventive and useful (or applicable to industry). The fourth concerns the way in which the subject matter is described in the written patent specification: this must be sufficient to enable the skilled worker to make practical use of the information given." (Beier et al., 1985).

There are some problems which arise when one considers the application of the above criteria in matters involving living organisms. One issue concerns the nature of the inventive process. The Supreme Court in Germany in 1969, in a case involving patentability of an animal breeding process, departed from the historical interpretation of the concept of patentable invention and recognized that innovations involving methodical utilization of controllable natural forces to achieve a causal, perceivable result could be considered patentable, provided they meet the general prerequisites of industrial application, novelty, advance in the art and inventive merit. "By those criteria, a completely artificial gene may be patentable. If the protein that the new gene makes and the organism into which the gene is inserted are also novel and seem to have desirable qualities, the inventor may sometimes extend the patent claim to include them as well" (Barton, 1991). The problem arises when one considers patenting useful genes found in nature. Traditional patenting doctrines rejected claims of property rights for "discoveries" that are not inventions. Even if the products were engineered but identical to products found in nature, no grants of property rights were permitted.[49]

The desire to encourage investment in biotechnological research led to the evolution of new, more liberal, doctrines in some countries which permit patenting of materials which are not found in nature in pure forms. Barton (1991) observed: "Although the law in such cases is both confusing and changing, it is likely to evolve in a generally reasonable direction. The starting point in the U.S. is a long-standing doctrine that the purified form of a chemical can be patented if the chemical

---

[49] This is still the law in Canada where the court in the Abitibi case stated that "The organism to be claimed should not of course have existed previously in nature for in that event the inventor did not create it and his invention is old" (Beier et al., 1985). The courts in Great Britain also defined its standards for innovation more severely "Its courts recently held that a naturally occurring gene sequence could not be patented" (Barton, 1991).

is found in nature only in an unpurified form. This rule permits the first person to isolate a pure protein, or the gene that encodes the protein, to patent it".

The requirement of description and reproducibility of the innovation may cause some difficulties. Advancements in biotechnologies may permit more exact descriptions. Modifications in patent systems which allow the use of material deposits to supplement written descriptions solved the problem at least for materials for which depositories are available at a reasonable cost. As we have noted earlier there are practical and moral difficulties in having deposits of higher life forms. There are also questions about the extent to which reproduction of some higher life forms is stable, i.e., the extent to which it results in an homogeneous output.

Another practical question in defining IPs involving living organisms relates to the scope of protection. "The obvious example of such a technical question is whether a patent should be regarded as reaching the progeny of a patented life form. By traditional law, the seller of a patented item exhausts his or her rights in the item, so that the buyer is entitled to use it as he or she sees fit. By definition, however, the reproduction of a patented article is an infringement of the patent" (Barton, 1993). The resolution of the conflict between these two doctrines should depend on the attributes of specific cases. In some cases, to obtain the benefits from the innovation the buyer must reproduce it as he uses it; in other cases, reproduction may mean developing products in competition with the patent holder.

An important concern in dealing with living organisms is to ensure that biodiversity is not reduced due to monopolization of genetic materials and inhibition of experimentation and research. The danger is that a broad scope of protection may prevent others from experimenting with improved genetic materials or attempting to improve materials found in nature for which IP was already assigned. Narrowing the scope of protection and exempting certain activities (e.g., research) from such protection may be indicated in such circumstances.

The conflicting demands that must be reconciled through an IP protection policy led to the emergence of forms of protection which admit innovations which may not satisfy criteria for patenting, or which for other reasons are excluded from patenting, but offer less IP protection than patenting. Breeder's rights protection and plant patents are examples of such mechanisms.

6.2.1 Protecting Breeder's Rights

A shift from the public sector to the private sector of efforts to improve genetic materials used in agriculture, and the difficulties of providing IP protection for traditional breeding activities under patent laws, led to the emergence of plant variety protection mechanisms. The objectives were to encourage the use of improved materials and protect farmers' interests. In their design they reflect a compromise between the need to give breeders some means for appropriating benefits from their improvements of genetic stock, while ensuring continuing access of other breeders to the improved materials so that the improvement process will continue. Exemptions provided by plant variety protection laws reflect the concern for farmers and growers. Despite these compromises, breeders' rights protection is one of the few forms of intellectual property protection that has been shown to increase innovation (Barton, 1993; Butler and Marion, 1985).[50]

The generally accepted criteria for protection of plant varieties are simpler to meet than the criteria of patenting and reflect the special characteristics of the traditional breeding process which involves the use of predictable ("obvious") processes. The emerging international doctrine was codified in the International Convention for the Protection of New Varieties of Plants (the UPOV Convention) concluded in Paris on 2nd of December, 1961 and revised in 1978 to harmonize with the U.S. Plant Variety Protection Act of 1970. The Convention was an agreement between countries to provide a minimum level of protection for new varieties on the basis of standard criteria (member states were allowed to provide stronger protection). The criteria for obtaining protection for a new variety under the Convention require it to be (1) distinguishable by one or more key characteristics from any other variety whose existence is common knowledge at the time of application, (2) homogeneous in terms of particular features of its sexual reproduction on vegetative propagation and (3) stable in its essential characteristics.

The process of showing that a new variety meets these criteria is much cheaper than the process of meeting patentability requirements under regular patent laws. Generally, the definitions of novelty are rather liberal and no requirements for "inventive ingenuity" are stipulated.

To achieve the goals of continued access to improved materials by other breeders and to encourage wide use of improved materials, the rights of a breeder are quite severely restricted. Thus, for example, the 1961 Convention limited the right of the breeder to exclude users. Breeder's prior authorization for use is required only for commercial production and the marketing of reproductive or vegetative propagating material of the variety (i.e. the commercial sale of seeds). Farmers, for example, are allowed to use harvested crop for seed. The Convention does not provide for rights to forbid distribution of the plant and products of the variety outside the propagation stage. It does not allow the breeder to prevent or demand compensation for the use of the variety in the process of generating new varieties and the commercial use of such varieties.

The Convention forbade "double protection" of a variety by both patents and Plant Breeders' Certificates. To accommodate the U.S., it was excluded from this provision, thus allowing U.S. breeders' to apply for both patents and breeders' certificates if they so wished.

---

50 Barton (1991) notes that there is limited but moderately supportive empirical evidence which shows that, on balance, patents actually favour innovation. Perhaps the most cited example is the perceived positive effects of the U.S. Plant Variety Protection Act (1970): "In the decade following passage of the act, the number of newly protected types of soy beans rose from 94 to 224, of wheat from 139 to 231, and of cotton from 64 to 96; expressed as a ratio, this represented increases of 141, 66 and 50 per cent respectively. Private investment in plant research from 1970 to 1980 in the U.S. increased at a ratio of 2:3, and decisive significance must be given to the fact that all this resulted in no increased costs in the market. Similar positive effects can be observed in the case of the British Plant Varieties and Seeds Act of 1964. Since its passage, the success of breeders in raising the disease resistance of wheat alone led to savings of 170 million pounds sterling within a period of 10 years" (Beier et al. 1985).

Technological changes have led to demand for plant variety protection models with higher levels of protection. Demands to enlarge the scope of breeders' rights and to extend them *inter alia* to all production of propagating material have been motivated by the advent of modern tissue culture and the possibility "that a person planting an orchard or other plantation can buy one plant which he propagates to plant a whole orchard or plantation with no obligation to the breeder in respect of the propagated material" (Greengrass, 1993). Another extension of protection sought concerns the use of a variety as a basis for developing new varieties. Under the traditional models of plant variety protection, a protected variety may be used as a source of initial variation. The resulting variety may be freely exploited by the breeder with no obligation to the developer of the initial variety if it is distinguishable by one or more important characteristics from the original variety. "Since the word 'important' in this context has been construed to mean 'important for the purposes of making a distinction' and not 'important in the sense of having value,' this has meant that a person selecting a mutant or a minor variant from an existing variety, or inserting an additional gene into it by back-crossing or some other procedure, can protect the resulting variety without rewarding the original breeder for his contribution to the final result" (Greengrass, 1993).

To prevent such a situation the principle of retaining breeders rights when "essential derivation" is involved was proposed. It requires a breeder of a variety which is "essentially derived" from another variety to obtain the authorization of the breeder of the protected variety. "A variety is deemed to be essentially derived from another variety ("the initial variety") for this purpose when (a) it is predominantly derived from the initial variety or from a variety that is itself predominantly derived from the initial variety while retaining the expression of the essential characteristics that result from the genotype or combination of genotypes of the initial variety; (b) it is clearly distinguishable from the initial variety; (c) except for the differences which result from the act of derivation, it conforms to the initial variety in the expression of the essential characteristics that result from the genotype or combination of genotypes of the initial variety" (Greengrass, 1993).

Examples of techniques which are likely to produce a variety "essentially derived" from a protected variety include natural or induced mutation, or with respect to a somoclonal variant, the selection of a variant individual from plants of an initial variety, back-crossing, or transformation by genetic engineering (see Seay, 1993).

The 1991 amendments to the UPOV Convention met the above concerns, by extending breeder's rights[51] to the production of propagating material and extended protection to varieties which are essentially derived from the protected variety. In addition, the 1991 Convention abolished the prohibition on double protection, extended breeder's rights to harvested material and required all members to protect varieties of all plant genera and species. These amendments must be ratified by members and converted to national law to have a formal impact[52] (Barton, 1993).

---

[51] The farmer's exemption to use saved seed for propagation was left as an option because of political pressures. Thus, for example, the EC Regulation on Plant Variety Rights limits the exemption but does not eliminate it completely. The U.S. Plant Variety Protection Act will probably continue to have farmer's exemption provisions.

[52] Canada, for example, has ratified the Convention but has not yet amended its Breeder's Right Act to conform to the requirements of the Convention.

6.2.2 Plant Patents

The U.S. is perhaps the only major country with a special patent provision for plant varieties which are asexually reproduced. The provisions of the Plant Patent Act (1930) authorize the granting of a plant patent to asexually reproduced varieties (other than tuber propagated) which are distinct, new, not obvious and described completely as reasonably as possible. The plant patent extends protection not only to inventions but also to discoveries. "There is a split of authority as to whether a plant patent covers independent derivation of a plant having the same varietal characteristics or only covers plant material actually derived from the patentee's plant. The majority of reported decisions to date require that the patentee demonstrates such derivation to establish infringement" (Seay, 1993, p. 63).

6.2.3 Trends in Patenting Multicellular Organisms

In 1985 the U.S. Patent Office accepted that a new variety of corn (*Ex Parte Hibberd*) with higher yields of tryptophan was an invention. It refused to protect the resulting seeds on the basis of section 2 of the Act of the 1978 UPOV Convention. The Supreme Court reversed the decision and decided to grant a patent on all aspects of the invention. Thus plants were deemed to be patentable by a utility patent irrespective of whether or not they were covered by breeders' rights protection.

In a watershed decision (Diamond vs. Chakrabarty) the U.S. Supreme Court decided in 1980 that section 101 of the U.S. Patent Act defining the word "invention" did not exclude living matter. The test for patentability was solely determined on whether the innovation resulted from human intervention.

In April 1987 the Board of Appeals of the U.S. (in *Ex Parte Allen*) ruled that polyploid oysters were a patentable subject matter. Following this decision, the U.S. Patent Office announced it would consider non-naturally occurring non-human multicellular living organisms including animals, to be patentable matter.

In April 1988 the first animal patent was issued to Harvard University. The patent was for a genetically engineered mouse that was designed to be very susceptible to cancer (Montgomery, 1990). Thus in the U.S. all multicellular organisms, with exception of humans, may be patentable as long as there is human intervention in creating them.

The U.S. patent system provides a benchmark for IP protection of living organisms. Japan has a similar concept of patenting with a few specific exceptions relevant to biotechnological inventions as to patentable subject matter.[53] In a majority of countries, however, there are doubts about the precise nature of protection available for living material. "In a count in 1989, some 57 countries expressly excluded plant varieties from patent protection, and in many cases these same

[53] Japanese patents are usually quite narrow in their scope as opposed to U.S. patents.

countries did not offer a special form of plant variety protection" (Greenpeace, 1993). Most of these countries however were developing countries. In Western Europe, most countries exclude plant varieties from patenting, as per the European Patent Convention. However, the practice of patent offices in interpreting the Convention is affected by several court cases which allowed patenting with respect to claims pertaining to categories of plants broader than varieties. For example, the decision in the Propagating Material/CIBA-Geigy case implies that, provided the innovator does not claim a plant variety or does not seek to protect specific plants possessing the attributes of a variety, he or she can seek a patent for the innovation. The claim, for example, for patenting the incorporation to plants of resistance to some insects, may be valid if it applies to a broad class of plants.

The European law with respect to patenting transgenic animals is informed by the decision of the Procedural Remedies Chamber (Decision T 19/90, Oct. 3, 1990) which reversed the rejection by the Division of Examination of a Harvard University application to patent its transgenic mouse. It interpreted the exclusion in the European Patent Convention (article 53b) of "plant or animal varieties" not to exclude animals in general, but rather only animal races. It also decided that, in judging the morality of the invention, animal suffering and risks to the environment must be balanced with the benefits of the invention. The Examining Division that was asked to review its previous decision to reject the patent granted the patent on May 1992. In its judgment it came to the conclusion that the application is not directed at an animal variety. The Division also provided analysis of the costs and benefits of the invention. It identified the following three interests which were involved and required balancing: (1) the cure of cancer, (2) protection of the environment from unwanted genes, (3) cruelty to animals. It concluded that the invention cannot be considered immoral or contrary to "ordre public" (Teschemacher, 1993).

Recently, the EC Directive on the Legal Protection of Biotechnology Inventions reached the final stage of approval. The Directive seeks to harmonize IP protection legislation with respect to biotechnological invention in the Community. To be implemented, member states must enact the provisions of the regulation amending their national laws. The proposal for the Directive was first tabled in 1988. The delays in the legislative process reflect various objections raised with respect to the patenting of plants and animals. The directive does not exclude from patenting biological material including plants and animal parts other than plant and animal varieties. However, it contains provisions which allow member countries to provide latitude in defining non-patentable subject matter.

In Canada, the current law does not exclude the patenting of animals or plants (it does exclude the patenting of plant varieties). The decision of what are patentable invention categories and what are excluded are a matter for government policy. At present, no decision to allow patenting of multicellular organisms has been made.

6.3 International Agreements and Commitments which must be Respected by Canada in Designing its IP Protection System

A country's IP protection policy will presumably reflect (1) its experience with IP protection, (2) the particular circumstances that mould the social welfare consequences of different levels of protection in the country and (3) the specific weights which are placed on the multiple objectives of protection. Some of the measures taken to limit or expand the breadth of protection may be specifically targeted while others may affect the general level of protection and the rewards offered to innovators. Degrees of freedom in changing domestically optimal IP protection policies are constrained. The choice cannot be made in isolation from choices of IP policies of other countries and the international obligations of the country in question. Indeed, we have already identified the minimal parameters of protection of varieties embodied in the Act of UPOV Conventions to which Canada must comply. Below we identify some of the other international agreements in which Canada is a party (or is about to join).

The Paris Union Convention of which Canada is a member (July 7, 1884) is a universal treaty establishing certain rights for IP protection for residents and nationals of its member countries under laws of other member countries. In 1967, the World Intellectual Property Organization was created to administer the Paris Union. (It became a U.N. agency in 1974). The most important principle of the Paris Union Convention is that of national treatment. It accords residents of member countries in a foreign member country the same protection rights as those accorded residents of the foreign member country. A second important right granted by the Convention is the right of priority. A resident of a country can file a patent first in any member country and then file in any other member country within 12 months of original filing, with subsequent filings enjoying the right of priority established by the first filing date. "The right of priority could be particularly significant for biotechnology inventions, since the 12 months period may be essential to comply with culture deposit requirements" (OTA, 1989, p. 156). The Convention also places several limitations on the ability of member countries to impose a compulsory licence or require other types of access to the innovation (e.g., require the patentee to make freely available a sample of a deposited organism to competitors which may be advantageous to those competitors).

An important international treaty for biotechnology is the Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedures (The Budapest Treaty). The treaty was signed in 1980 and entered into force in 1983. Canada could not become a member until amendments were made to its Patent Act (Bill C-15, CS-17 1993) to allow acceptance of deposits of strains of microorganism to satisfy the disclosure requirements of subsection 36(1) of the Patent Act. Canada is likely to sign the treaty soon. According to the treaty, a culture collection may become designated as an International Depository Authority (IDA), and any deposit of microorganisms to it will satisfy deposit requirements under members' patent laws. The Budapest Treaty provides the rules of deposit for IDA's. It requires IDA's to store deposited microorganisms for at least 5 years after the most recent request of a sample from it, and for at least 30 years from the date of the original deposit. Samples of deposited culture can be released to patent offices, to parties authorized by them and other parties legally entitled to receive the sample (e.g., competitors).

Article 1709 of the North American Free Trade Agreement (NAFTA) requires members to make patents available for "original inventions whether products or processes, in all fields of technology, provided that such inventions are new, result from an inventive step and are capable of industrial application". (The Article defines "inventive step" and "capable of industrial application" to be synonymous with the terms "non-obvious" and "useful" respectively). It does allow exclusion of patentability to protect ordre public or morality, including protection of human, animal or plant life or health or avoidance of serious prejudice to nature. The NAFTA allows the exclusion of "plants and animals other than microorganisms and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes". The GATT/TRIPS agreement sets minimum IP protection levels for all members but provides for exclusion for medical treatments and higher life forms.

Canada is also bound by the Biodiversity Convention (signed by Canada in 1991 and ratified in 1992). The Convention recognizes the need for industrial users of genetic resources to share the benefits of improved genetic resources with those countries that provide the initial resources. The Convention requires that sharing the benefits and technology transfer take place within the framework of existing IP protection laws in a way which is fair to all parties. The Convention guarantees the sovereignty of states over their genetic resources and forbids their appropriation without prior consent (Simpson et al., 1994).

There are other international agreements which, though not legally binding, must be considered in developing and applying an IP protection system dealing with biotechnological innovations. The U.N. Food and Agriculture Organization (FAO) developed a global system for managing plant genetic resources consisting of the International Undertaking, the Commission and the International Fund (FAO, 1993). The system includes a code for collection and transfer of germplasm, biotechnology networks, periodical publications and an international fund based on the concept of farmers' rights. The idea underlying "farmers' rights" was to apportion value in improved materials to the initial materials and the technology. The system was also motivated by concern for the developing world. Experience in agriculture (especially in developing countries) showed that compensation for patented genes and the fees to gain access to protected varieties proved too expensive for farmers. Patents stopped breeders from using the best genetic materials. In the development of the system, attempts by FAO to ensure free access for developing countries to improved materials encountered strong objections from developing countries which were concerned with the rights of innovators. The industrial countries added to the emerging policy documents the concept of breeders' rights. In meetings of the FAO Commission on Plant Genetic Resources and at the FAO Conference (1993) the principle that plant genetic resources are a common heritage of humankind was further clarified: "... it has been stressed that "free access" does not mean free of charge, and it has been pointed out that the principle of a common heritage is not incompatible with national sovereignty. Through the discussions surrounding the recognition of Plant Breeders' Rights and Farmers' Rights and the establishment of the International Fund for Plant Genetic Resources, the participants have recognized the need to establish a mechanism or mechanisms to reward breeders and to compensate farmers throughout the world - especially in developing countries - for having developed and preserved, over generations, the plant genetic resources now being utilized, and for making those resources available to today's breeders and scientists" (FAO, 1993).

The international framework emerging from the FAO discussions and UNCED 1992 are compatible, emphasizing the need to provide access to genetic materials and compensate the custodians of biodiversity. The FAO approach puts more emphasis on the development of a common fund to aid developing countries to gain access to improved genetic materials and promote conservation, while the recognition of sovereign rights of states over their natural resources in the U.N. Convention of Biological Diversity (1992) implies the development of material transfer agreements which presumably will ensure that the source nation will receive a share of the profits (Barton, 1993). Indeed, Simpson, Sedjo and Reid (1994) report that "Organizations in many countries are now entering into commercial agreements with foreign pharmaceutical researchers; the most noted of these is probably that signed between Merck and Company, a large U.S. pharmaceutical firm, and Costa Rica's *Instituto Nacional de Biodiversidad* (INBio). This agreement involved a fixed payment of some one million dollars and promises of substantial royalties in the event of new product discovery" (Simpson et al., 1993).

The "international" factor in designing an IP policy for Canada must reflect not only our international agreements and commitments but also our position as an open economy dependent on exports. IP protection policies serve as strategic tools to attract innovators to Canada, to preempt international competitors from accessing certain innovations and to defend access for Canadian companies to certain fields of innovation. Indeed, the extension of a country's IP protection beyond its borders (e.g., barring imports of products produced using a domestically protected technology without authority in a country where the technology is unprotected), which is contained in the 1991 Act of the UPOV Convention and in proposed laws of several countries, is bound to increase the strategic use of IP protection policies in trade. Strategic considerations for offering protection mechanisms may also arise when a local company can obtain priority in foreign countries by filing in its own country (e.g., domestic filing provides a firm with a 12 month period in which it can file elsewhere without losing its claim for priority). A more accommodating domestic application process may provide a firm with a 12 month period to accommodate tougher requirements in other countries.

6.3.1 Transfer Agreements

A problem which has risen internationally because of patenting is the preservation of a free flow of genetic materials, especially those conserved in public (national and international) gene banks. Agreements between national governments and the FAO concerning a network of *ex situ* collections have been prepared. The objective is to facilitate access to germplasm for scientific and technological use. The register of base collections of the International Plant Genetic Resource Institute (IPGRI) will be merged with collections of the FAO's network and the International Agricultural Research Centers of the CGIAR. The worry is that others with access to the materials may patent improvements and reduce future access to the materials and possible improvements of the materials. Instead of using defensive patents to make materials freely available, material transfer agreements have been proposed. This mechanism requires those who intend to make commercial products from the materials to come and negotiate terms and conditions. Material transfer agreements can also be used by the private sector to facilitate research while protecting commercial interests. Since higher plant germplasm is very difficult to describe verbally and usually impossible to duplicate from description, researchers and breeders require physical access to it. In principle, research exemption from IP protection is desirable but may force firms to seek protection through secrecy. The development of a comprehensive standardized framework for material transfer or exchange agreements and some form of compulsory licensing is likely to reduce the negative impacts on innovation that patenting may have by constraining the flow of germplasm to researchers and breeders.

A reduction in the transaction costs of effecting and administering these agreements is required to facilitate their use. Furthermore, there is a need to ensure that early (pre-patent) exchange of materials through an agreement would cause a forfeiture of the right to patent (i.e., the requirement in many countries for absolute novelty may need to be modified) (see Baenziger et al., 1993).

6.4 Who Do Patents Protect?: Reflection on the Transaction Costs of Obtaining and Enforcing IP Protection

In deciding on an IP protection policy it is necessary to consider different aspects of costs associated with maintaining the system, the costs of obtaining protection and the costs of enforcing protection. These costs may vary significantly as a function of the subject matter of protection and the type of mechanisms used for protection. "Intellectual property rights are meaningless unless enforced (and for software copyright, where the grant of rights is essentially automatic, enforcement is the only context in which litigation comes to the surface). Enforcement is, in the first instance, a litigation issue, but litigation is so expensive that its economics shapes the effective scope of intellectual property rights. A patent that its holder cannot afford to defend is worthless; likewise, a patent claim can be significantly stretched against a firm unable to afford defensive litigation. Equally important, intellectual property licenses - whose pattern differs radically from industry to industry - dramatically shape the real-world impact of these rights" (Barton, 1993).

Patent litigation is very expensive especially in emerging science-based emerging fields, such as biotechnology, that create new issues and are surrounded by uncertainty. The high costs are "a nearly absolute bar to use of the system by small firms: where they must use the system, as in the biotechnology industry whose pharmaceutical products are easily imitated, the resulting costs are likely to drain away research funds. Some biotechnology firms are said to be spending more on litigation than on research" (Barton, 1993, p. 275). Indeed, the "deep pockets" of large corporations can be used to pre-empt entry of new firm through threats of litigation (Silverman, 1990).

The expense associated with filing for a patent are quite high in the biotechnology field. Use of plant variety or plant patents which require less rigorous proofs of novelty are less expensive. Seay (1993), for example, observed that in the U.S. "there may be a cost advantage, in most circumstances, to proceed by way of plant patent rather than a utility patent. Plant patents may involve less attorney preparation and filing time and may avoid deposit costs". Filing under the Plant Variety Protection Act in the U.S. is also much simpler and more certain than filing for a utility patent (e.g., there is no requirement to show inventive ingenuity). The narrower scope of protection under the Plant Variety Protection Act reduces risks of rejection and reduces the chance of infringement. Furthermore, the lower economic value of protection is likely to reduce the chance of "strategic litigation". Finally, one must consider the costs to the public purse of running an efficient IP protection policy. The decision with respect to patentable subject matter must consider the process of verification and filing. Thus, for example, if deposits of materials are required for patenting of living organisms, it is necessary that appropriate facilities are made available. If the costs are high and are shifted to inventors, then small innovative companies would not be able to afford protection. Finally, a system must be able to validate claims in a timely manner and therefore have the appropriate infrastructure (e.g., information systems) and skilled personnel. This is more expensive in a technological field which is rapidly changing.

6.5 Summary

This section provides a review of some of the key aspects involved in decisions concerning IP protection of inventions containing living organisms. It reviews some of the major public policy concerns underlying the decisions about the level of protection offered. Lack of protection may promote secrecy and reduce the incentives to innovate. High levels of protection may delay revelation of information and reduce the flow of germplasm to researchers and breeders. Design of an IP protection policy must consider a range of protection mechanisms which provide the optimal levels of protection for specific classes of subject matter; these will reflect the specific attributes and the profiles of costs and benefits from anticipated innovations in each class of subject matter. Often the question of appropriate level is one that can be answered precisely only empirically (i.e., the level of protection can be modified on the basis of experience). The paper suggests, however, that an IP protection policy cannot be designed in isolation from the country's international obligations and the IP protection policies of other countries. The design must consider the strategic uses of IP protection policy in trade and investment promotion. Finally the paper points out the importance of transaction costs involved in implementing an IP protection system. An expensive system where the costs are borne by users may affect the industrial organization of the innovative sector and may lead to a reduction in competition and innovation rates.

The application of the arguments of the paper to the forestry sector suggest a convex net benefit function of IP protection levels. The importance of concerns for biodiversity, the "science push" nature of, and the public sector role in, this research and innovation field, the presence of many small companies, international concerns for equity and the high transaction costs involved in patenting suggest that neither very high levels of protection nor absence of protection are likely to be socially optimal. Mechanisms such as Plant Variety Protection may offer the appropriate balance of tradeoffs.

7.0 CONCLUSION AND POLICY RECOMMENDATIONS

There are two major application areas in forestry which may involve new multicellular organisms: (a) the improvement of trees, (b) pest control.

Time will remain a major constraint in the progress of tree improvement programs. The long breeding and testing processes which are required for commercial applications make tree improvement more difficult, costly and uncertain compared to the improvement of many agricultural crops. Similarly, the high uncertainties involved in the research and development process reduce the commercialization potential of activity in this area, particularly since lower risk, more "conventional" breeding and improvement techniques are available. Another factor which has been found to discourage commercial R&D by private producers, especially in the plywood, sawmill and pulpmill areas, is the competitive structure of production and the resulting rapid transfer of benefits to consumers. To some extent, vertical integration in the industry mitigates some of this concern; however, the relatively atomistic organization of the wood products segment of the industry suggests that producers will have relatively short time horizons and limited amounts of capital to perform long-term R&D projects. Genetic engineering is likely to expand the range of microorganisms that can be used as delivery systems for biotoxins. Great interest is now shown by researchers in the introduction of viruses as means of delivering toxins to insects. The use of larger organisms as predators to control insect population is also being experimented with. The use of multicellular organisms for this purpose, however, is limited by both economic and ecological concerns.

There are distinctive characteristics of forestry biotechnology which suggest that, in the short-run at least, the risks of erring on the side of weak patent protection are relatively low. The present values of expected profits from inventions with long terms to payoff are relatively low, so the prospect of private funding is not significant, in any case. Patent protection with normal terms to maturity will not change this imperative. Moreover, patents may not be as important in the protection of intellectual property in the forestry sector as they are in other biotechnology applications. Relevant notions here include the following observations: (i) while the basic research elements of the application of biotechnology to forestry are well known, the "art" of processing and preparation of products is proprietary and is often protectable by secrecy; (ii) many of the research results (especially in the field of somatic seeds) do not have a universal application and often require a close relationship between the producers of biotechnology and the users (e.g., forest products companies, nurseries, etc.). This also implies lower risk that the technology developed can be readily appropriated for use by other firms. This conclusion may be less appropriate in the case of biopesticides than in the cases of improved seeds and bioprocessing. The market for biopesticides is well developed with a significant presence of large diversified companies that produce both chemical and biological pesticides for forestry and agriculture. In this market, the role of governments in funding and producing applied research is rather minor and commercial imperatives are fairly immediate. Hence, in the case of biopesticides in particular, other factors conditioning the welfare impacts of patenting may be of particular relevance.

Review of the institutions involved in seed forest biotechnology research points to limited pre- and post-patent competition, as well as the prominence of government funded R&D. Research on somatic seed is limited at present to a few organizations that specialize in regional specific species. An implication is that pre-patent competition may be limited. Furthermore, at least in this area of research for the foreseeable future, patent protection in any country is likely to protect the intellectual property of local R&D performers. In biopesticides for forestry applications, four companies supply 92% of the global market demand. There are no significant Canadian players in the market. The relevance of patent protection in Canada to forestry biotechnology R&D is moot given the small number of Canadian R&D performers, as well as the dominance of government and publicly funded projects in the area. Potential commercial players, however, require patenting, since access to investment capital is often contingent on intellectual property protection.

The demand functions that Canada faces for its major commodity exports are inelastic in the short and mid term. Innovations which increase exports are likely to result in price and revenue decreases. While producers (domestic) surpluses may decline, the benefits to consumers will accrue mainly to foreign consumers. In the long run one must consider the effects of higher prices on the introduction of substitutes. Canada with a large inventory of forest resources has a strategic interest in preventing price ranges that induce permanent substitution. Indeed environmental regulations in Canada and the U.S. have already pushed lumber prices to levels which may provide incentives for builders to change construction technologies and substitute for some of the wood products used in construction. Higher fibre prices combined with environmental regulation and public demand for greener products, have led to a higher use of recycled fibre. Thus innovation which increases forest productivity (e.g., improved trees with higher growth rates) should be encouraged if a long time horizon is considered for the social welfare calculation. Unfortunately because of the existing system of incentives rooted in the dominant tenure systems and the public ownership of the resource, IP protection policies are not likely to stimulate Canadian private sector innovations that lead to improved forest productivity. Innovations that are targeted to short term cost cutting in forestry and processing, insurance and product differentiation are likely to result in improved social welfare. Such innovations are likely to be stimulated by strong IP protection, though the specificity of innovations given differences in the resource endowment between regions may lessen the importance of stronger protection.

For the foreseeable future at least, participants on the "supply side" of the forestry biotechnology market (defined to encompass biopesticides and herbicides) will tend to be relatively specialized in terms of their innovation activities. Moreover, they seem to be focusing on problems particularly relevant to local users, so that the benefits of their innovation activities tend to be concentrated within specific segments of the industry. All of this suggests that innovators in this area may be able to internalize more of the benefits than is true in the case of innovation, more generally. In addition, those benefits not captured by local producers may be captured by local users, and will be retained by local users to the extent that the latter enjoy market power in the downstream markets in which they operate. As such, Canada may not have strong reasons to rely upon patent protection as a vehicle to promote forestry biotechnology. Since Canadian producers as a whole are not pure price takers in softwood lumber, pulp and newsprint sectors, cost reductions stemming from innovations will not necessarily be passed through completely to consumers, the bulk of whom are non-Canadians. Innovations which facilitate product differentiation will yield the bulk of the benefits to producers. In the broad segments of the industry which face competitive markets, final consumers (mainly foreigners) will be substantial long-run beneficiaries of competitive innovation in the industry.

Balancing the different economic impacts of strong IP protection in the forestry-related biotechnology sector and considering only economic arguments, the analysis provides a weak case for a strong domestic patent protection regime for forestry biotechnology. The economic arguments suggest that incentives to perform forestry R&D are influenced more strongly by ownership arrangements in the industry and by patent regimes elsewhere than by the patent regime in Canada. On the margin, some additional R&D in activities such as biopesticides might be stimulated by stronger domestic patent protection; however, offsetting this consideration are the higher prices for patented products (by foreign firms) Canadians would pay for these products. Since the bulk of biotechnology R&D in these activities is done by foreign firms, the "balance of trade" for Canada is likely to be worsened by stronger intellectual property protection.

Non-economic considerations in patenting living organisms are perhaps more important to the articulation of an IP policy concerning multicellular organisms. Arguments against patenting living organisms can be raised on a variety of bases that the economic paradigm fails to consider. Some of the concerns raised are:

- Environmental considerations: Some opponents of patenting living organisms argue that environmental protection policies are not well developed to deal with such innovations. Limiting IP protection may slow the innovation process and consequently result in a smaller probability of environmental harm. Another argument against strong patenting of living organisms is based on threats to biodiversity. It is argued that strong patenting imposes constraints on the free flow of genetic materials and provides incentives to reduce genetic variation.

- Theological and moral arguments: Some arguments especially directed at the patenting of transgenic animals are raised on the basis of metaphysical and theological concerns, including arguments that patenting promotes a materialistic conception of life and raises issues of the integrity of species and the sanctity of human life. Others focus on issues of animal suffering and inappropriate control over animal life.

- Equity considerations: Some advocates against strong patenting of living organisms raise questions of international and domestic equity. These arguments are especially targetted at the patenting of useful genes found in nature. It is argued that farmers and consumers, especially in less developed countries, may have to pay royalties on products that are based on their own biological resources and knowledge.

- Implementation problems: Some objections to the patenting of multicellular organisms stem from practical implementation problems or the high transaction costs involved (e.g., the need to develop appropriate depositories when other means of description of a new organism are inadequate).

- High Costs of Enforcement Considerations: High costs of enforcement and uncertainties with respect to claims of patents involving new organisms create opportunities for firms with "deep pockets" to engage in strategic litigation using the patent law to deny others their rights to the fruits of their R&D or to pursue opportunities for invention.

Objections which are based on ethical and metaphysical arguments must be left to the political arena and the courts. Some of the objections are based on false scientific assumptions or perceptions (e.g., protecting the integrity of species) while others are concerned with potentially inappropriate use of innovations and public risks that can result from such use. With respect to the latter, we argue that one must not confuse laws which settle property rights to innovations with laws and regulations which control their production and use. These objections to patenting life are based on the belief that by reducing the level of protection for a class of innovations, one will reduce the incentive to innovate, the rate of innovation and the risks associated with the innovation. In "science push" innovative sectors such as biotechnology, this direct form of risk reduction is highly ineffective. Even if the rate of innovation declines, there will not be effective control of the type and use of the innovations which occur. Indeed scientific curiosity may lead to inventions which commercial common sense may reject. Lack of IP protection is likely to increase secrecy and reduce the ability of society to monitor innovations and their consequences. Lack of information may delay regulatory moves to protect society or even make them impossible or impractical. Thus direct and well targeted regulation of the use and production of innovations provides more effective protection and is more efficient than indirect control through IP protection policies. Other objections (e.g., the equity distribution and biodiversity concerns) can be dealt with through a modification of patenting laws.

There is almost universal acceptance of patenting microorganisms. The trend internationally, though less consistent, is to permit the patenting of multicellular organisms but to tighten regulation of their introduction to the environment and their eventual use. With respect to the forest product sector, patenting policies with respect to animals are of little economic consequence. The use of multicellular organisms as effective agents of pest control is not likely to assume a significant role for the next decade. Indeed, research on biopesticides based on bacteria and viruses is dominant. The relative ease of producing microorganisms compared to the difficulty of raising multicellular animals is likely to keep research on biopesticides focused on the former.

IP protection of plants is already available in Canada (and most of the industrialized countries) through breeder's rights protection mechanisms (which following the implementation of the 1991 Act of the UPOV Convention will provide higher levels of protection). It is our view that from a purely domestic perspective, once the Breeder's Rights Act is revised to meet the 1991 Convention requirements, it will provide an appropriate balancing of concerns for maintaining the flow of germplasm to breeders while providing sufficient incentives to innovators. Strategic arguments for stronger patenting may be made on the basis of Canada's future ability to attract investment in Canadian biotechnology companies; however, these arguments are not very compelling. The regulatory environment, access to venture capital markets and the scientific and human capital resources available in Canada are probably the dominant factors in attracting innovative companies to Canada. IP protection policies will play a significant but relatively minor role in the location decision of biotechnology companies.

BIBLIOGRAPHY

Agrow Consulting, *B.t. in Crop Protection*, PJB Publications Ltd., Surrey, U.K., 1993.

Arif, B.M., Forest Pest Management Institute, Sault Ste. Marie; personal communication, 1994.

Barton, John H., "Patenting Life", *Scientific American*, Vol. 264, No. 3, March 1991, pp. 40-46.

Barton, John H., "Ethnobotany and Intellectual Property Rights", mimeo, Oct. 5, 1993, p. 3.

Barton, John H., "Adapting the Intellectual Property System to New Technologies", in *Global Dimensions of Intellectual Property Rights in Science and Technology*, Mitchell B. Wallerstein, Mary Ellen Mogee, and Roberta A. Schoen (eds.), National Academy Press, Washington, D.C. 1993.

Beier, F.K., R.S. Crespi, and J. Straus, *Biotechnology and Patent Protection: An International Review*, Organisation for Economic Co-operation and Development (OECD), Paris, 1985.

Berkowitz, M.K., and Y. Kotowitz, "Patent Policy in an Open Economy", *Canadian Journal of Economics*, Vol. 15, No. 1, 1982, pp. 1-17.

Blain, F., Communications Office, PFC, Canadian Forest Service; personal communication, 1994.

Booth, D., "The impact of product and geographic diversification strategies on corporate performance in the North American forest products sector", FEPA Working Paper 115, January, 1989.

Booth, D., and I. Vertinsky, "Strategic positioning in a turbulent environment: an empirical study of determinants of performance in the North American forest industry", *Forest Science*, Vol. 32, 1991, pp. 903-923.

Bourbonnais, R., L. Jurasek and M.G. Paice, "Biotechnology in the Pulp and Paper Industry", Report prepared for the National Biotechnology Advisory Committee, April, 1991.

Butler, L., and B. Marion, "The Impacts of Patent Protection on the U.S. Seed Industry and Public Plant Breeding", North Central Regional Research Publication 304, September 1985.

Canadian Forest Service, "Business opportunity document: weed biocontrol agents", Pacific Forestry Centre, Victoria, B.C., 1994.

Cartwright, D., "The Canadian forest industry: present situation and future trends" Appendix 2 of the study by Gaston and Cohen, 1993.

Caves, R.E., and M.E. Porter, "From Entry Barriers to Mobility Barriers: Conjectural Decisions and Contrived Deterrence to New Competitions", *Quarterly Journal of Economics*, Vol. 91, 1977, pp. 241-262.

Cheliak, W.M., and D.L. Rogers, "Integrating biotechnology into tree improvement programs", *Canadian Journal of Forest Research*, Vol. 20, 1990, pp. 452-463.

Cockburn, Iain, and Zvi Griliches, "Industry Effects and Appropriability Measures in the Stock Market's Valuation of R&D and Patents", working paper 2465, National Bureau of Economic Research, December 1987.

Cohen, D., and S.A. Sinclair, "Forward vertical integration for Canadian and U.S. producers of structural panels and softwood lumber: trends of the 1980s", *Forest Products Journal*, Vol. 41, No. 1, 1991, pp. 46-52.

Cohen, D., and C. Gaston, "NAFTA: trading opportunities for the British Columbia wood industry", FEPA Working Paper, August, 1993.

Crick, F.H., and J.D. Watson, "The complementary structure of deoxyribonucleic acid", *Proceedings of the Royal Society* (A) Vol. 223, 1954, pp. 80-96.

Deloitte and Touche Management Consultants, *Economic Benefit Assessment of Spruce Budworm Control in Eastern Canada*, Guelph, Ontario, 1992.

DeYoe, D., and W. Scowcroft, *The Role of Biotechnology in the Regeneration of Canadian Forests*. Prepared for BIOFOR, Canada, 1988.

Dorworth, C., "The Pacific Forestry Center Microherbicide Program: principles and practice", in C. Dorworth and S.G. Glover (eds.), *Biocontrol of Forest Weeds*, Pacific Forestry Center, 1992, pp. 1-12.

Dorworth, C., Pacific and Yukon Centre, Canadian Forest Service, personal communication, 1994.

Duvick, Donald N., "Goals and Expectations of Industry for Intellectual Property Rights for Plant Materials" in *Intellectual Property Rights: Protection of Plant Materials*, P. Stephen Baenziger, Roger A. Kleese, and Robert F. Barnes (eds.), CSSA Special Publication Number 21, Proceedings of workshop held Jan. 26-28, 1993, pp. 21-27.

Gallini, Nancy, "Patent Policy and Costly Initiation", *RAND Journal of Economics*, Vol. 23, Spring 1992, pp. 51-63.

Gilbert, Richard, and Carl Shapiro, "Optimal Patent Length and Breadth", *RAND Journal of Economics*, Vol. 21, Spring 1990, pp. 206-212.

Gilbert, Richard, and Daniel Newbery, "Preemptive Patenting and the Persistence of Monopoly", *American Economic Review*, September 1982.

Globerman, Steven, and Richard Schwindt, "The Organization of Vertically Related Transactions in the Canadian Forest Products Industries", *Journal of Economic Behavior and Organization*, Vol. 7, 1986, pp. 199-212.

Grabowski, Henry G., and John M. Vernon, "The Pharmaceutical Industry" in Richard R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Analysis*, New York, Pergamon Press, 1982, pp. 283-360.

Greengrass, Barry, "Non-U.S. Protection Procedures and Practices - Implications for U.S. Innovators?" in *Intellectual Property Rights: Protection of Plant Materials*, P. Stephen Baenziger, Roger A. Kleese, and Robert F. Barnes (eds.), CSSA Special Publication Number 21, Proceedings of a workshop held Jan. 26-28, 1993, pp. 41-59.

Haines, Russell, *Biotechnology in Forest Tree Improvement*, FAO, Rome, forthcoming.

Hammatt, N., "Progress in the biotechnology of trees", *World Journal of Microbiology and Biotechnology*, 8(4), July, 1992, pp. 369-377.

Haynes, R., and D. Adams, "The timber situation in the United States", *Journal of Forestry*, May, 1992, pp. 38-43.

James G. Heller Consulting Inc., "Background Economic Study of the Canadian Biotechnology Industry", report submitted to Environment Canada, Health Canada and Industry Canada, Nov. 1994.

Hyde, William F., David H. Newman, and Barry J. Sheldon, *The Economic Benefits of Forestry Research*, Ames: Iowa State University Press, 1992.

Karrfalt, R., USDA National Tree Seed Laboratory, Dry Branch, Georgia; personal communication, 1994.

Kitch, Edward, "The Nature and Function of the Patent System", *The Journal of Law and Economics*, October 1977.

Klemperer, Paul, "How Broad Should the Scope of Patent Protection Be?" *RAND Journal of Economics*, Vol. 21, Spring 1990, pp. 113-130.

Kostenmeier, Robert, Report, in *Transgenic Animal Patent Reform Act of 1989: Hearing* Subcommittee on courts, intellectual property, and the Administration of Justice of the Committee on the Judiciary, House of Representatives, Sept. 13 and 14, 1989, Washington, D.C., pp. 416-498.

Langford, Jock, and Dave Blaker, "The Role of Intellectual Property in the Competitiveness of the Pharmaceutical Sector", *1991 Pharmaceutical Review*, Consumer and Corporate Affairs Canada, October 1991.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter, "Appropriating the Returns from Industrial Research and Development", *Brookings Papers on Economic Activity*, Vol. 3, 1987, pp. 783-831.

McFetridge, D.G., and M. Rafiquzzaman, "The Scope and Duration of the Patent Right", in John Palmer, ed., *The Economics of Patents and Copyrights*, Greenwich, Conn.: JAI Press Inc., 1986, pp. 91-120.

Mansfield, Edwin, Mark Schwartz, and Samuel Wagner, "Imitation Costs and Patents: An Empirical Study", *Economic Journal*, Vol. 91, December 1981, pp. 907-918.

Merges, Robert, and Richard Nelson, "Market Structure and Technological Advantage: The Role of Patent Scope Decisions", Berkeley: University of California, mimeo, 1990.

Montgomery, M.T., "Building a Better Mouse -- and Patenting It: Altering the Patent Law to Accomodate Multicellular Organisms", *Case Western Reserve Law Review*, V.4, 1990, pp. 231-265.

Mowery, David, and Nathan Rosenberg, "The U.S. National Innovation System", University of California at Berkeley, Consortium on Competitiveness and Cooperation, Working Paper No. 90-3, September 1990.

Mullin, T.J., *Making Choices – Seedling and Clonal Options for Breeding and Reforestation in New Brunswick*, Truro, Nova Scotia, 1992.

Namkoong, G. and H. Kong, "Quantitative genetics of forest trees", in J. Janick (ed.), *Plant Breeding Reviews*, Vol. 8, Timber Press, Portland, Oregon, 1990, pp. 139-188.

Nelson, Richard, "What is Public and What is Private About Technology", Berkeley: University of California, mimeo, September, 1990.

Nordhaus, William D., *Invention, Growth and Welfare*, Cambridge: M.I.T. Press, 1969.

NRC Plant Biotechnology Institute, Annual Report, 1993.

Office of Technology Assessment, *New Development in Biotechnology: Patenting Life*, Congress of U.S., OTA, Washington, D.C., No. 5, April, 1989.

Office of Technology Assessment, *Biotechnology in a Global Economy*, Congress of the U.S., OTA, Washington, D.C., October 1991.

Oum, T. and M. Tretheway, "A Comparison of the Productivity Performance of the U.S. and Canadian Pulp and Paper Industries", FEPA Working Paper 113, May, 1988.

Oum, T. and M. Tretheway, "A Comparison of the Productivity Performance of the Canadian, U.S. and Swedish Pulp and Paper Industries", FEPA Working Paper 132, March, 1989.

Pimentel, *et al.*, "Environmental and Economic Costs of Pesticide Use", *BioScience*, Vol. 42, No. 10, 1992, pp. 750-760.

Porter, M., *Competitive Strategy*, New York: The Free Press, 1980.

Pulp and Paper International (PPI), "Bottom line needs an urgent face lift", Vol. 35, No. 9, September, 1993.

Roberts, D., Levesque Beaubien Geoffrion, Ottawa. Personal communication, 1993.

Rumelt, R., *Strategy, Structure and Economic Performance*, Cambridge, Mass.: Harvard University Press, 1974.

Runyon, K.L., "Canada's Timber Supply: Current Status and Outlook", *Information Report*, E-X-45, Forestry Canada, 1991.

Scotchmer, Suzanne, "Standing on the Shoulders of Giants: Cumulative Research and Patent Law", *Journal of Economic Perspectives*, Vol. 5, Winter 1991, pp. 29-41.

Scotchmer, Suzanne, and Jerry Green, "Novelty and Disclosure in Patent Laws", *RAND Journal of Economics*, Vol. 21, Spring 1990, pp. 131-146.

Seay, Nicholas J., "Intellectual Property Rights in Plants" in *Intellectual Property Rights: Protection of Plant Materials*, P. Stephen Baenziger, Roger A. Kleese and Robert F. Barnes (eds.), CSSA Special Publication Number 21, Proceedings of workshop held Jan. 26-28, 1993, pp. 61-78.

Sharma, Prakash, "Optimal Patent Term and Trade: Some Considerations on the Road Ahead", External Affairs and International Trade Canada, Policy Staff Paper No. 93/12, October 1993.

Silverman, H., "Symposium Report: Intellectual Property Law and the Venture Capital Process", *High Tech Law Journal*, 5:157, 1990.

Simpson, R. David, Roger A. Sedjo, and John W. Reid, "Valuing Biodiversity: An Application to Genetic Prospecting", Resources for the Future, Discussion Paper 94-20, March 1994.

Smith, D., Program Manager of the Biotechnology Division, Tissue Culture Research Group, New Zealand Forest Research Institute; personal communication, 1994.

Smyth, J.H., and A.J. Brownwrite, *Forest Tree Production Centres in Canada: 1984*, Great Lake Forestry Centre, Canadian Forest Service, Information Report O-X-378, 1986.

Stanbury, W., and I. Vertinsky, "Europe 1992: threat or opportunity for the Canadian forest products industry and implications for public policy", *The Forestry Chronicle*, Vol. 67, No. 6, December, 1991.

Sutton, B.C.S., B.C. Research Institute; personal communication, 1994.

Sutton, B.C.S., "Somatic Embryogenesis and Tree Improvement in Interior Spruce", *Journal of Forestry*, October, 1993.

Teschemacher, Rudolf, "Legislation, Existing Practice in the EPO, Japan and USA", Conference Document for the Symposium Biotechnology and Intellectual Property, November 23-24, 1993, Stockholm.

Trotter, Patrick, "Biotechnology in the Pulp and Paper Industry: A Review. Part 1: Tree Improvement, Pulping and Bleaching, and Dissolving Pulp Applications", *Tappi Journal* 73(4), April, 1990, pp. 198-204.

U.N. Food and Agriculture Organization (FAO), *Biotechnology in Agriculture, Forestry and Fisheries*, Rome, 1993.

United States Department of Agriculture (USDA) Forest Service, *Tree Planting in the United States - 1993*, USDA, Washington, D.C., 1994.

Ursacki, T., "The internationalization of the Japanese pulp and paper industry: implications for Canada", FEPA Working Paper 172, 1992.

van Frankenhuyzen, Kees, "The challenge of Bacillus thuringiensis", in *Bacillus thuringiensis, An Environmental Biopesticide: Theory and Practice*, P.F. Entwistle, J.S. Cory, M.J. Bailey and S. Higgs (eds.), John Wiley and Sons, New York, 1993.

Waterson, Michael, "The Economics of Product Patents", *The American Economic Review*, Vol. 80, No. 4, September 1990, pp. 860-869.

Weiser, J., "Impact of the Bacillus thuringiensis on applied entomology in eastern Europe and the Soviet Union", in *Mitterlungen aus der Biologischen Bindesonstalt für Lund-und Forstwirtschaft Berlin-Dahlem*, A.K. Kreg and A.M. Huger (eds.), Paul Poney, Berlin, 1986, pp. 37-50.

Wood Technology, North American Factbook 1993-94, Miller Freeman Inc., 1993.

Wyatt, Sally, G. Bertin, and K. Pavitt, "Patents and Multinational Corporations: Results from Questionnaires", *World Patent Information*, Vol. 7, No. 3, 1985, pp. 196-212.

Table 1
Production of World Forest Products
1980-1991

	1980	1985	1990	1991	1991 Share in Aggregate	Compound Annual Growth Rate 1980-85	Compound Annual Growth Rate 1985-91
Roundwood (million m3)							
Industrial Roundwood							
Softwood	992.0	1053.9	1181.5	1074.8	31.3	1.2	0.3
Hardwood	459.5	469.8	530.2	524.4	15.3	0.4	1.8
Total	1451.5	1523.7	1711.6	1599.3	46.6	1.0	0.8
Other Roundwood	1477.4	1656.6	1795.0	1830.2	53.4	2.3	1.7
Total	2928.9	3180.4	3506.6	3429.4	100.0	1.7	1.3
Lumber (million m3)							
Softwood	335.5	350.5	372.7	326.7	71.4	0.9	-1.2
Hardwood	115.8	117.8	133.0	130.8	28.6	0.3	1.8
Total	451.3	468.3	505.7	457.5	100.0	0.7	-0.4
Wood-Based Panels (million m3)							
Veneer	4.4	5.0	5.0	5.1	4.2	2.4	0.5
Plywood	39.4	44.8	47.8	47.6	38.9	2.6	1.0
Particleboard	40.2	43.0	50.4	49.5	40.4	1.4	2.3
Fibreboard	17.0	18.1	20.2	20.2	16.5	1.3	1.9
Total	101.0	110.9	123.4	122.4	100.0	1.9	1.7
Wood Pulp (million mt)							
Mechanical	26.6	30.2	36.5	36.1	23.9	2.6	3.0
Semi-chemical	7.6	7.2	7.7	7.5	5.0	-1.1	0.6
Chemical							
Unbleached sulphite	5.8	5.3	3.2	2.4	1.6	-2.0	-12.2
Bleached sulphite	5.2	4.6	5.4	5.6	3.7	-2.6	3.3
Unbleached kraft	34.1	34.6	34.7	34.5	22.9	0.3	-0.0
Bleached kraft	40.5	46.7	60.1	63.1	41.9	2.9	5.1
Total*	86.8	93.8	105.6	107.1	71.1	1.5	2.2
Dissolving wood pulp	4.8	4.4	4.3	4.0	2.7	-1.7	-1.4
Total*	121.1	131.2	149.8	150.7	100.0	1.6	2.3
Paper and Paperboard (million mt)							
Newsprint	25.4	28.2	32.8	32.4	13.3	2.1	2.3
Printing & Writing	41.2	50.2	68.7	70.0	28.8	4.0	5.7
Other Paper, Paperboard	103.6	114.6	137.6	141.0	57.9	2.0	3.5
Total	170.3	193.0	239.1	243.5	100.0	2.5	4.0

* Totals do not added

Source: FAO (1993), Forest Products Yearbook, 1991.

Table 2
World Forest Products by Major Commodity Aggregates
1980-1991 and Projected 2010

	1980	1985	1990	1991	2010	1991 Share in World	Compound Annual Growth Rate 1980-85	1985-91	1991-2010
TOTAL LUMBER									
Production (000 m3)									
Canada	44324	54586	54906	52040		11.4	4.3	-0.8	
United States	84112	88361	109800	103893		22.7	1.0	2.7	
Former USSR	98200	98200	105000	75500		16.5	0.0	-4.3	
Japan	36955	28472	29781	28264		6.2	-5.1	-0.1	
China	21010	27243	23160	20521		4.5	5.3	-4.6	
Brazil	14881	17781	17179	17179		3.8	3.6	-0.6	
ROW	151804	153622	165860	160080		35.0	0.2	0.7	
Total	451286	468265	505686	457477		100.0	0.7	-0.4	
Exports (000 m3)									
Canada	29326	39004	37937	36980		42.2	5.9	-0.9	
United States	5834	4534	9022	9434		10.8	-4.9	13.0	
Sweden	5915	7898	6252	6941		7.9	6.0	-2.1	
Malaysia	3320	2830	5332	4982		5.7	-3.1	9.9	
Former USSR	7242	7732	6230	4780		5.5	1.3	-7.7	
Finland	6939	4898	4176	4288		4.9	-6.7	-2.2	
ROW	21080	19134	20045	20124		23.0	-1.9	0.8	
World	79656	86030	88994	87529		100.0	1.6	0.3	
Imports (000 m3)									
Canada	1613	1354	1561	1486		1.7	-3.4	1.6	
United States	22918	34610	31369	28135		32.6	8.6	-3.4	
Japan	5573	5244	9038	9400		10.9	-1.2	10.2	
United Kingdom	6632	7002	10661	7280		8.4	1.1	0.7	
Italy	5774	4909	5999	6054		7.0	-3.2	3.6	
Germany	6879	5729	6059	5045		5.9	-3.6	-2.1	
ROW	28356	26792	29400	28772		33.4	-1.1	1.2	
World	77745	85640	94087	86172		100.0	2.0	0.1	
Consumption (000 m3)									
Canada	16611	16936	18530	16546	26905	3.6	0.4	-0.4	2.6
United States	101196	118437	132147	122594	156596	26.9	3.2	0.6	1.3
Former USSR	91314	90772	98970	70895	127016	15.5	-0.1	-4.0	3.1
Japan	42471	33694	38789	37653	38889	8.3	-4.5	1.9	0.2
China	21104	27832	24134	21425	78149	4.7	5.7	-4.3	7.0
Germany	18972	16433	19522	18925	24192	4.1	-2.8	2.4	1.3
ROW	157707	163771	178687	168082	293253	36.9	0.8	0.4	3.0
World	449375	467875	510779	456120	745000	100.0	0.8	-0.4	2.6

Table 3
World Forest Products by Major Commodity Aggregates
1980-1991 and Projected 2010

	1980	1985	1990	1991	2010	1991 Share in World	Compound Annual Growth Rate 1980-85	1985-91	1991-2010
WOOD-BASED PANELS (VENEER, PLYWOOD, PARTICLEBOARD, FIBREBOARD)									
Production (000 m3)									
Canada	4802	6063	6358	5555		4.5	4.8	-1.4	
United States	26224	30870	32086	30409		24.8	3.3	-0.3	
Former USSR	10618	12549	12701	11490		9.4	3.4	-1.5	
Germany	8307	8034	9635	10049		8.2	-0.7	3.8	
Indonesia	1012	4919	7802	9594		7.8	37.2	11.8	
Japan	10280	8964	8614	8387		6.9	-2.7	-1.1	
ROW	39787	39532	46236	46941		38.3	-0.1	2.9	
Total	101030	110931	123432	122425		100.0	1.9	1.7	
Exports (000 m3)									
Canada	1344	1819	2506	1983		6.6	6.2	1.4	
United States	986	936	3161	3158		10.5	-0.7	22.5	
Japan	245	4097	8402	8344		27.7	75.7	12.6	
Germany	1360	1355	2060	2096		6.9	-0.1	7.5	
United Kingdom	604	784	1390	1703		5.6	5.4	13.8	
China	833	1261	1368	1393		4.6	8.6	1.7	
ROW	10969	9094	11585	11495		38.1	-3.7	4.0	
World	16323	19346	30472	30172		100.0	3.5	7.7	
Imports (000 m3)									
Canada	233	299	535	575		2.0	5.1	11.5	
United States	2145	3658	4225	3661		12.5	11.3	0.0	
Japan	315	676	3821	4121		14.0	16.5	35.2	
Germany	2263	2054	3252	3150		10.7	-1.9	7.4	
United Kingdom	2446	3200	3318	2811		9.6	5.5	-2.1	
China	50	550	2069	2155		7.3	61.5	25.6	
ROW	8203	8711	12489	12884		43.9	1.2	6.7	
World	15655	19148	29709	29357		100.0	4.1	7.4	
Consumption (000 m3)									
Canada	3691	4543	4387	4147	15035	3.4	4.2	-1.5	7.0
United States	27401	33592	33150	30912	86453	25.4	4.2	-1.4	5.6
Japan	10448	9459	12342	12418	26699	10.2	-2.0	4.6	4.1
Germany	9737	8827	11519	11806	19813	9.7	-1.9	5.0	2.8
Former USSR	9849	11724	11953	10979	29808	9.0	3.5	-1.1	5.4
China	1462	2539	4767	5219	15043	4.3	11.7	12.8	5.7
ROW	37774	40049	44551	46129	120149	37.9	1.2	2.4	5.2
World	100362	110733	122669	121610	313000	100.0	2.0	1.6	5.1

Table 4
World Forest Products by Major Commodity Aggregates
1980-1991 and Projected 2010

	1980	1985	1990	1991	2010	1991 Share in World	Compound Annual Growth Rate 1980-85	1985-91	1991-2010
WOOD PULP									
Production (000 m3)									
Canada	19945	20222	22835	23306		15.1	0.3	2.4	
United States	46187	49061	57217	58896		38.1	1.2	3.1	
Japan	9773	9279	11321	11722		7.6	-1.0	4.0	
Sweden	8699	9123	9909	9885		6.4	1.0	1.3	
Former USSR	8824	10374	10394	8662		5.6	3.3	-3.0	
Finalnd	7246	7977	8886	8483		5.5	1.9	1.0	
ROW	25146	29500	33527	33735		21.8	3.2	2.3	
World	125820	135536	154089	154691		100.0	1.5	2.2	
Exports (000 m3)									
Canada	7244	7024	7884	8776		33.3	-0.6	3.8	
United States	3392	3415	5360	5753		21.8	0.1	9.5	
Sweden	3052	3038	2768	2710		10.3	-0.1	-1.9	
Finland	1939	1534	1461	1348		5.1	-4.6	-2.1	
Portugal	445	879	1057	1093		4.1	14.6	3.7	
Brazil	890	930	1033	1033		3.9	0.9	1.8	
ROW	4226	4959	5395	5642		21.4	3.3	2.2	
World	21188	21779	24958	26355		100.0	0.6	3.2	
Imports (000 m3)									
Canada	141	220	232	186		0.7	9.3	-2.8	
United States	3652	3983	4439	4533		17.3	1.8	2.2	
Germany	2630	3092	3668	3807		14.6	3.3	3.5	
Japan	2206	2252	2869	2906		11.1	0.4	4.3	
Italy	1760	1811	2099	2352		9.0	0.6	4.5	
France	1755	1609	1905	1957		7.5	-1.7	3.3	
ROW	8464	8661	10024	10417		39.8	0.5	3.1	
World	20608	21628	25236	26158		100.0	1.0	3.2	
Consumption (000 m3)									
Canada	12842	13418	15183	14718		9.5	0.9	1.6	
United States	46447	49629	56296	57676		37.3	1.3	2.5	
Japan	11879	11511	14172	14617		9.5	-0.6	4.1	
Former USSR	8224	9578	9944	8212		5.3	3.1	-2.5	
Sweden	5695	6219	7333	7354		4.8	1.8	2.8	
Finland	5343	6505	7506	7229		4.7	4.0	1.8	
ROW	34810	38525	43933	44688		28.9	2.0	2.5	
World	125240	135385	154367	154494		100.0	1.6	2.2	

Table 5
World Forest Products by Major Commodity Aggregates
1980-1991 and Projected 2010

	1980	1985	1990	1991	2010	1991 Share in World	Compound Annual Growth Rate 1980-85	1985-91	1991-2010
NEWSPRINT									
Production (000 m3)									
Canada	8625	8991	9069	8977		27.7	0.8	-0.0	
United States	4238	4923	6001	6206		19.2	3.0	3.9	
Japan	2674	2592	3479	3515		10.8	-0.6	5.2	
Sweden	1534	1594	2273	1971		6.1	0.8	3.6	
Former USSR	1354	1565	1780	1550		4.8	2.9	-0.2	
Finalnd	1569	1811	1430	1305		4.0	2.9	-5.3	
ROW	5419	6766	8719	8880		27.4	4.5	4.6	
World	25413	28242	32751	32404		100.0	2.1	2.3	
Exports (000 m3)									
Canada	7707	8275	8722	8561		56.1	1.4	0.6	
United States	159	285	527	729		4.8	12.4	16.9	
Sweden	1238	1352	1772	1561		10.2	1.8	2.4	
Finland	1432	1643	1203	1159		7.6	2.8	-5.7	
Norway	523	761	822	795		5.2	7.8	0.7	
Germany	91	181	429	379		2.5	14.7	13.1	
ROW	1171	1443	1901	2069		13.6	4.3	6.2	
World	12321	13940	15376	15253		100.0	2.5	1.5	
Imports (000 m3)									
Canada	0	0	0	0		0.0	--	--	
United States	6594	7686	7529	6797		45.7	3.1	-2.0	
Germany	914	909	1235	1361		9.2	-0.1	7.0	
United Kingdom	1077	1242	1308	1328		8.9	2.9	1.1	
Japan	127	330	435	462		3.1	21.0	5.8	
France	371	318	498	442		3.0	-3.0	5.6	
ROW	3508	3691	4440	4475		30.1	1.0	3.3	
World	12591	14176	15445	14865		100.0	2.4	0.8	
Consumption (000 m3)									
Canada	918	716	347	416		1.3	-4.8	-8.7	
United States	10673	12324	13003	12274		38.3	2.9	-0.1	
Japan	2073	2841	3788	3822		11.9	1.0	5.1	
Germany	1535	1562	2050	2216		6.9	0.3	6.0	
United Kingdom	1382	1561	1859	1851		5.8	2.5	2.9	
Former USSR	1064	1204	1493	1324		4.1	2.5	1.6	
ROW	8472	9474	11773	11437		35.7	2.3	3.2	
World	25683	28478	32820	32016		100.0	2.1	2.0	

Table 6
World Forest Products by Major Commodity Aggregates
1980-1991 and Projected 2010

	1980	1985	1990	1991	2010	1991 Share in World	Compound Annual Growth Rate 1980-85	1985-91	1991-2010
TOTAL PAPER AND PAPERBOARD (INCLUDING NEWSPRINT)									
Production (000 m3)									
Canada	13390	14448	16466	16559		6.8	1.5	2.3	
United States	56839	60959	71965	72724		29.9	1.4	3.0	
Japan	18008	20469	28088	29053		11.9	2.6	6.0	
China	6867	11197	17057	18538		7.6	10.3	8.8	
Germany	8822	10475	13224	13540		5.6	3.5	4.4	
Former USSR	8733	10031	10718	9590		3.9	2.8	-0.7	
ROW	57603	65386	81532	83472		34.3	2.6	4.2	
World	170262	192965	239050	243476		100.0	2.5	4.0	
Exports (000 m3)									
Canada	9555	10157	11875	11945		20.7	1.2	2.7	
United States	4186	3221	5388	5966		10.3	-5.1	10.8	
Finland	4868	6260	7633	7524		13.0	5.2	3.1	
Sweden	4626	5302	6613	6086		10.5	2.8	2.3	
Germany	1862	3095	4208	4535		7.9	10.7	6.6	
Austria	886	1426	2185	2623		4.5	10.0	10.7	
ROW	9125	11511	17767	19026		33.0	4.8	8.7	
World	35106	40972	55669	57707		100.0	3.1	5.9	
Imports (000 m3)									
Canada	260	540	962	968		1.7	15.7	10.2	
United States	8054	10434	11685	10744		19.0	5.3	0.5	
Germany	4057	4644	7012	7624		13.5	2.7	8.6	
United Kingdom	3510	4598	5597	5527		9.8	5.5	3.1	
France	2109	2432	3791	3786		6.7	2.9	7.7	
Netherlands	1435	1543	2420	2547		4.5	1.5	8.7	
ROW	14372	16068	24142	25470		44.9	2.3	8.0	
World	33797	40259	55609	56666		100.0	3.6	5.9	
Consumption (000 m3)									
Canada	4095	4831	5553	5582	10591	2.3	3.4	2.4	3.4
United States	60707	68172	78262	77502	113422	32.0	2.3	2.2	2.0
Japan	17901	20374	28280	29092	48962	12.0	2.6	6.1	2.8
China	7342	11834	17713	19612	53239	8.1	10.0	8.8	5.4
Germany	11017	12024	16028	16629	25126	6.9	1.8	5.6	2.2
United Kingdom	6832	7752	9421	9238	15319	3.8	2.6	3.0	2.7
ROW	67889	75017	93154	94018	176341	38.8	2.0	3.8	3.4
World	168951	192252	238990	242435	443000	100.0	2.6	3.9	3.2

Note: Germanyh includes the former German Democratic Republic.

Source: FAO (1983), Forest Products Yearbook 1991, Rome; and FAO (1993), Forestry Statistics Today for Tomorrow 1961 -- 1991, 2010

Table 7
Total Forested Areas (1,000 ha) in 1990

Region	Forest	% World Total
Africa	535,848	15.7
Zaire	113,275	3.3
South America	898,184	26.3
Brazil	561,107	16.5
Asia	426,221	12.5
China[a]	127,780	3.7
Indonesia	109,549	3.2
Europe	140,196	4.1
Sweden	24,437	0.7
Finland	20,112	0.6
Oceania	87,700	2.6
Australia	39,837	1.2
North America	530,744	15.6
Canada	247,164	7.2
United States	209,573	6.1
Former U.S.S.R.	754,958	22.1

[a] Based on 1980 data.

Source: Food and Agriculture Organization of the United States, *Forestry: Statistics Today for Tomorrow*, Rome 1993.

Table 8
Sawnwood (1991)

Producer Country	($1000m^3$)	Consumer Country	($1000m^3$)
1. United States	103,893	1. United States	122,594
2. Former U.S.S.R.	75,500	2. Former U.S.S.R.	70,895
3. Canada	52,040	3. Japan	37,653
4. Japan	28,264	4. China	21,425
5. China	20,521	5. Germany	18,925
6. India	17,460	6. India	17,443
7. Brazil	17,179	7. Brazil	16,965
8. Germany	15,158	8. Canada	16,546

Table 9
Wood-Based Panels (1991)

Producer Country	(1000m^3)	Consumer Country	(1000m^3)
1. United States	30,409	1. United States	30,912
2. Former U.S.S.R.	11,490	2. Japan	12,418
3. Germany	10,049	3. Germany	11,806
4. Indonesia	9,594	4. Former U.S.S.R.	10,979
5. Japan	8,387	5. China	5,219
6. Canada	5,555	6. Italy	4,663
7. Italy	4,156	7. Canada	4,146
8. France	3,586	8. France	3,828

Table 10
Pulp for Paper and Waste Paper (1991)

Producer Country	(1000mt)	Consumer Country	(1000mt)
1. United States	59,136	1. United States	79,462
2. Canada	23,348	2. Japan	29,136
3. China	14,111	3. China	20,439
4. Japan	11,129	4. Canada	16,466
5. Sweden	9,885	5. Germany	12,659
6. Former U.S.S.R.	9,017	6. Former U.S.S.R.	11,070
7. Finland	8,483	7. Sweden	8,039
8. Brazil	4,839	8. Finland	7,606

Table 11
Paper and Paperboard (1991)

Producer Country	(1000mt)	Consumer Country	(1000mt)
1. United States	72,724	1. United States	77,502
2. Japan	29,053	2. Japan	29,091
3. China	18,538	3. China	19,612
4. Canada	16,559	4. Germany	16,629
5. Germany	13,540	5. U.K.	9,239
6. Finland	8,505	6. Former U.S.S.R.	9,229
7. Sweden	8,355	7. France	8,861
8. France	7,442	8. Italy	7,154

Source: Food and Agriculture Organization of the United Nations, Rome, 1993, various tables.

Table 12
Canada's Forest Sector by Industry, 1980-91

	1980	1991	1991 Share by Industry	Compound Annual Growth Rate 1980-85	Compound Annual Growth Rate 1985-91
Logging					
# Establishments	3241	8015	67.5	2.9	13.6
Employees	54370	39972	15.9	-3.3	-2.3
Shipments (Cdn$ mill)	4559.3	7701.9	18.4	3.7	5.9
Value Added (Cdn$ mill)	2048.7	2914.2	18.3	1.3	4.9
Saw and Planing Mills					
# Establishments	1317	841	7.1	-1.7	-5.9
Employees	66278	48225	19.2	-2.3	-3.3
Shipments (Cdn$ mill)	5278.0	7728.1	18.5	5.4	2.0
Value Added (Cdn$ mill)	2088.5	2560.4	16.1	5.9	-1.4
Shingles and Shakes					
# Establishments	124	78	0.7	-2.9	-5.1
Employees	2034	1555	0.6	2.2	-6.1
Shipments (Cdn$ mill)	151.5	213.6	0.5	5.3	1.4
Value Added (Cdn$ mill)	66.1	78.8	0.5	3.2	0.3
Veneer and Plywood					
# Establishments	84	75	0.6	-0.5	-1.5
Employees	12363	7069	2.8	-6.0	-4.0
Shipments (Cdn$ mill)	839.8	857.5	2.0	1.1	-0.6
Value Added (Cdn$ mill)	344.5	372.6	2.3	1.4	0.1
Total Wood Industries*					
# Establishments	3363	3173	26.7	0.7	-1.5
Employees	117307	100656	40.1	-1.7	-1.1
Shipments (Cdn$ mill)	8397.0	13165.7	31.4	5.8	2.9
Value Added (Cdn$ mill)	3465.6	4978.7	31.2	6.2	1.0

Table 12 (cont'd)

	1980	1991	1991 Share by Industry	Compound Annual Growth Rate 1980-85	1985-91
Pulp and Paper					
# Establishments	144	155	1.3	-1.0	2.1
Employees	86872	75285	30.0	-2.2	-0.5
Shipments (Cdn$ mill)	10907.5	15446.4	36.9	4.2	2.4
Value Added (Cdn$ mill)	5355.0	5766.1	36.2	1.3	0.1
Other Paper Products					
# Establishments	620	526	4.4	-2.3	-0.8
Employees	43438	34801	13.9	-3.4	-0.8
Shipments (Cdn$ mill)	3595.3	5557.0	13.3	5.4	3.0
Value Added (Cdn$ mill)	1415.1	2289.6	14.4	5.0	4.0
Total Paper and Allied Products**					
# Establishments	764	681	5.7	-2.1	-0.2
Employees	130310	110086	43.9	-2.6	-0.6
Shipments (Cdn$ mill)	145028	21003.4	50.2	4.5	2.5
Value Added (Cdn$ mill)	6770.1	8055.7	50.5	2.1	1.1
Total Forest Industries (Logging, wood and pulp and paper)					
# Establishments	7368	11869	100.0	1.4	7.0
Employees	301987	250714	100.0	-2.4	-1.1
Shipments (Cdn$ mill)	27459.1	41871.0	100.0	4.8	3.2
Value Added (Cdn$ mill)	12284.4	15948.6	100.0	3.2	1.7

Value added is for total activity. Shipments are for goods of own making.

* Includes saw and planing mill, shingle and shake, veneer and plywood, millwork, box and other wood industries.

** Includes logging, wood products and pulp and paper products.

Source: Statistics Canada [various years]. Canadian Forestry Statistics. Catalogue 25-202.

Table 13
Capacity of Paper and Board and Pulp Mills, 1991-92
(1,000 tons)

Country	Number of Mills		Average Capacity	
	Paper and Board	Pulp	Paper and Board	Pulp
Canada	112	26	172	1,052
United States	544	207	148	301
Sweden	51	50	183	217
Finland	45	44	241	214
Former U.S.S.R.	161	50	69	216
Japan	444	55	75	275
China	250	176	64	63

Source: *Pulp and Paper International*, Vol. 35, No. 7, July 1993.

Table 14
Major Tree Species Used in Reforestation (Canada)

Species	% of Total Seed Utilized		
	1980	1982	1984
Jack pine	59.2	43.0	26.1
White spruce	21.8	23.6	44.9
Black spruce	5.6	17.8	18.4
Lodgepole pine	3.8	4.2	6.9
Interior spruce	2.8	1.6	1.2
Douglas-fir	1.1	1.0	1.2
White pine	1.0	1.5	1.1
Englemann spruce	-	1.0	1.0

Source: Schooley and Mullin, 1987.

Table 15
Sources of Seed Production as a Percentage of Total Yield in Canada

Seed Source	1980	1982	1984	1987 (forecast)
Total seed produced (billions)	7.62	14.34	12.27	7.3
General collections (%)	90.50	88.60	94.70	42.0
SCA plus SPA (%)	9.30	11.30	5.20	55.0
SO (%)	0.20	0.10	< 0.10	3.0

Source: Schooley and Mullin, 1987.

Table 16
Number of Conifer Seed Utilized in Canada by Province (in millions)

Province	1978	1980	1982	1984	1987
B.C. & Yukon	325	320.0	347	384	550
Alberta	1607	1137.0	895	2804	2406
Saskatchewan	203	136.0	192	65	1349
Manitoba	91	16.0	26	54	97
Ontario	1255	3230.0	2416	2753	1500
Quebec	170	623.0	918	1172	420
New Brunswick	92	123.0	350	-	288
Nova Scotia	23	77.0	80	-	107
Prince Edward Island	1	0.3	9	-	3
Newfoundland	381	41.0	56	49	611
Total	4148	5705.0	5291	7281	7331

Note: Figures for 1987 were based on forecast.

Source: Schooley and Mullin, 1987.

Table 17
Bare-root Seedling Production in Canada (1984)

Province	No. of Production Centres	Area Available for Production (ha)	Area Currently in Production (ha)	Trees shipped (000s)
B.C.	11	853	302	53,329
Alberta	2	100	36	9,600
Saskatchewan	4	151	83	10,647
Manitoba	1	38	24	2,700
Ontario	11	761	657	59,938
Quebec	8	387	387	47,400
New Brunswick	2	126	98	14,300
Nova Scotia	2	99	55	4,600
Prince Edward Island	1	20	4	315
Newfoundland	1	40	40	3,242
Total	43	2,575	1,686	206,071

Source: Smyth and Brownwright, 1986.

Table 18
Containerized Seedling Production in Canada (1984?)

Province	No. of Production Centres	Area Available for Production (m^2)	Trees Shipped ('000)
B.C.	26	240,395	74,702
Alberta	5	27,115	15,139
Saskatchewan	0	1,134	-
Manitoba	2	6,582	3,722
Ontario	32	77,979	81,458
Quebec	15	126,870	21,500
New Brunswick	9	53,316	39,802
Nova Scotia	8	27,407	12,073
Prince Edward Island	1	3,717	1,214
Newfoundland	3	3,204	2,439
Total	101	567,719	252,049

Source: Smyth and Brownwright, 1986.

Table 19
Seedling Production in Canada by Ownership, 1984

Province		Federal (%)	Provincial (%)	Industrial (%)	Private (%)	Trees Shipped ('000)
B.C.	bare-root	-	91.8	1.1	7.1	53,329
	container	-	47.4	11.5	41.1	74,702
Alberta	bare-root	-	97.9	-	2.1	9,600
	container	-	82.6	10.5	6.9	15,139
Saskatchewan	bare-root	-	100.0	-	-	10,647
	container	-	-	-	-	-
Manitoba	bare-root	-	100.0	-	-	2,700
	container	-	100.0	-	-	3,722
Ontario	bare-root	-	99.1	0.9	-	59,938
	container	-	13.6	-	86.3	81,458
Quebec	bare-root	-	99.4	-	0.6	47,400
	container	-	48.4	-	51.6	21,500
New Brunswick	bare-root	-	16.1	83.9	-	14,300
	container	-	68.9	31.1	-	39,802
Nova Scotia	bare-root	-	100.0	-	-	4,600
	container	-	37.5	25.9	36.6	12,073
Prince Edward Island	bare-root	-	100.0	-	-	315
	container	-	100.0	-	-	1,214
Newfoundland	bare-root	-	100.0	-	-	3,242
	container	-	100.0	-	-	2,439
Total	bare-root	-	91.5	6.4	2.1	206,071
	container	-	43.1	10.2	46.7	252,049

Source: Smyth and Brownwright, 1986.

Table 20
Public and Industry Funding for Site Preparation and Regeneration in Canada

1991	Public Funding		Industry Funding
	Site Preparation	Regeneration	All Silviculture Expenses
B.C.	$24,082,000	$75,741,000	$187,495,000
Alberta	n/a	n/a	$8,902,000
Saskatchewan	$404,000	$4,211,000	$2,730,000
Manitoba	$536,000	$1,814,000	$3,084,000
Ontario	$26,659,000	$31,647,000	$1,639,000
Quebec	$43,803,000	$90,331,000	$9,590,000
New Brunswick	$340,000	$8,044,000	$13,470,000
Nova Scotia	$731,000	$4,764,000	$4,965,000
Prince Edward Island	$686,000	$888,000	n/a
Newfoundland	$504,000	$2,359,000	$2,207,000

Source: Adapted from Canadian Council of Forest Ministers, *Compendium of Canadian Forest Statistics*, 1992.

Table 21
Forest Seed Certified in Canada Under the OECD Scheme for 5-year Periods Ending in the Years Indicated

Year	Seedlots Certified	Certificates Issued	Species	Weights of Seeds (kg)	Estimated Value of Overseas Market (Cdn$)
1975	127	930	9	7373	520,000
1980	173	710	8	8542	2,747,000
1985	165	665	7	8222	5,039,000
1990	140	719	5	8617	4,470,000
Ave.	151	756	7	8189	3,194,000

Source: Portlock, 1992.

Table 22
Forest Tree Seed Certification under the OECD Scheme in B.C. and Yukon, 1981-92

Year	Seedlots Certified	Certificates Issued	Species	Weights of Seeds (kg)	Estimated Value* of Overseas Market (Cdn$)
1981	27	112	2	1261	714,000
1982	46	138	5	1275	788,000
1983	33	161	6	2575	1,443,000
1984	29	85	1	927	678,000
1985	30	169	4	2184	1,416,000
1986	27	137	4	2269	573,000
1987	36	142	4	1001	883,000
1988	33	213	5	2608	1,554,000
1989	32	127	6	1354	727,000
1990	12	100	5	1358	733,000
1991	9	65	7	216	149,200
1992	15	143	7	1212	734,200
Total	329	1592		18267	9,811,400

Source: D.G.W. Edwards, 1988, "Forest tree seed certification in Canada under the OECD scheme and ISTA rules: 1981-1985 summary report", Information Report BC-X-299 Pacific Forestry Centre; F.T. Portlock 1992. "Forest tree seed certification in Canada under the OECD scheme and ISTA rules: 1986-1990 summary report", Information Report BC-X-332 Pacific Forestry Centre; and unpublished data from Pacific Forestry Centre.

* Estimated average values per kilogram of seeds:

B.C. sources: 1981-1983, $500
1984-1985, $600
1986-1990, $500
1991-1992, $600

Yukon sources: 1981-1985, $800
1986-1990, $1000
1991-1992, $1100

Table 23
The Development of Industrial Interest in B.t. During the 1980s

	Unmodified Strains	Improved Strains	Resistant Crops	Microbemediated Delivery
Pre-1980:				
- Abbott Laboratories	*			
- Biochem	*			
- Zoecon	*			
- Duphar	*			
Post-1980:				
- Abbott	*	*		
- Solvay/Duphar	*	*		
- Zoecon/Sandoz	*	*	*	
- Novo	*	*		
- Ciba-Geigy	*	*		
- ICI	*	*	*	
- Sumitomo	*	*		
- DowElanco	*	*		
- Ecogen	*	*		
- Mycogen	*	*		*
- Monsanto				*
- Rohm and Haas			*	
- Plant Genetics Systems			*	
- Agracetus			*	
- Calgene			*	
- Sungene Tech.			*	
- Agrigenetics				*
- Crop Genetics International			*	

Source: van Frankenhuyzen, K., "The Challenge of Bacillus thurungiensis", in *Bacillus thurungiensis, An Environmental Pesticide: Theory and Practice*, P.F. Entwistle, *et al.* (eds.), John Wiley and Sons, New York.

Table 24
Current Status of Forest Biotechnology Research in Canada

Institution	Research Activity	Species of Interest
British Columbia		
- Simon Fraser University, Vancouver	Nuclear cytoplasmic genome analysis	Douglas-fir
- Clay Nurseries, Langley	Conifer micropropagation	Yellow cedar, Douglas-fir
- Agriforest Industries, Kelowna	Micropropagation scale up; acclimation; rooting	Engleman spruce, lodgepole pine
Alberta		
- University of Calgary, Calgary	Conifer micropropagation; genetic transformation	Several including spruces, pines, cedar, larch, hemlock
- University of Edmonton, Edmonton	DNA analysis; genotype identification; cloning	Spruce, lodgepole pine
Saskatchewan		
- Plant Biotech Institute, Saskatoon	Conifer micropropagation	Douglas-fir, lodgepole pine
- University of Saskatchewan, Saskatoon	Somatic embryogenesis; protoplast culture	Spruce
Ontario		
- Petawawa National Forestry Institute, Chalk River	Somatic embryogenesis; DNA analysis; protoplast culture	Spruce, larch, poplar
New Brunswick		
- Maritime Forest Research Centre, Fredericton	Micropropagation; rejuvenation of adult material	Spruce, larch
Quebec		
- University of Laval, Quebec City	Micropropagation; genetic transformation	Larch, maple, birch

Source: DeYoe, D. and W. Scowcroft, 1988, *The Role of Biotechnology in the Regeneration of Canadian Forests*.

Figure 1

Some Linkages in Forest Products Industry

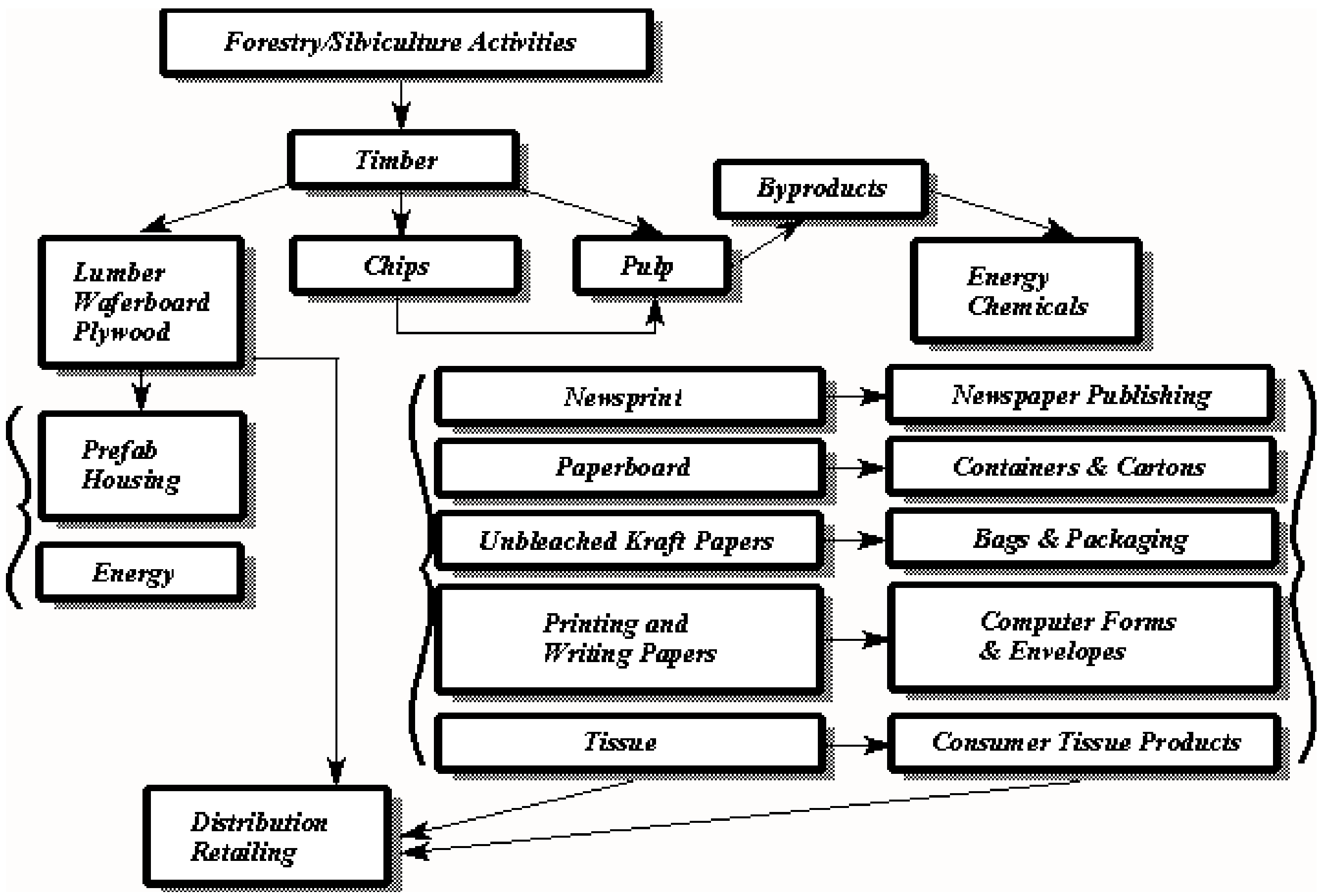

Figure 2

SYLVICULTURE
Millions of seedlings

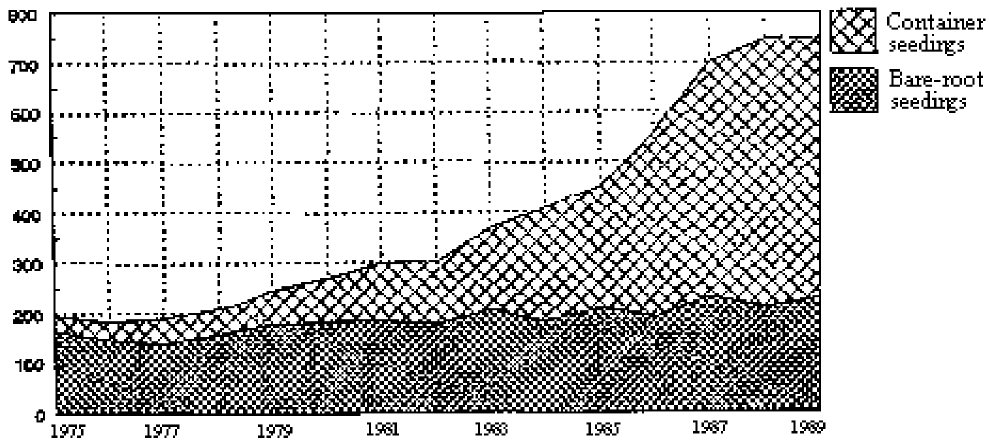

Figure 4. Artificial regeneration by stock type, 1975-1989.
Source: Kunkhe, D.H. Sylviculture statistics for Canada: an 11 year summary. Forestry Canada and unpublished figures 1986-1989. Kunkhe, D.H.; Smyth, J.H.; Lapointe G. Forest management Statistics for Canada, 1977-88. Canadian Pulp and Paper Association and Forestry Canada.

SYLVICULTURE
Millions of seedlings

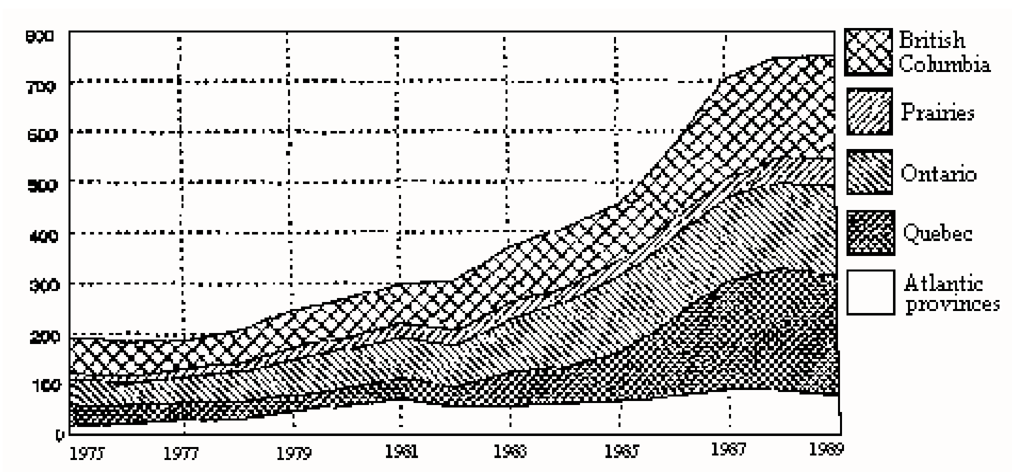

Figure 5. Artificial regeneration by region, 1975-1989.
Source: Kunkhe, D.H. Sylviculture statistics for Canada: an 11 year summary. Forestry Canada and unpublished figures 1986-1989. Kunkhe, D.H.; Smyth, J.H.; Lapointe G. Forest management Statistics for Canada, 1977-88. Canadian Pulp and Paper Association and Forestry Canada.

Reprinted from: Selected Forestry Statistics Canada, Forestry Canada, 1991.

Figure 3

Price and Output Consequences of a Cost-Reducing Process Innovation

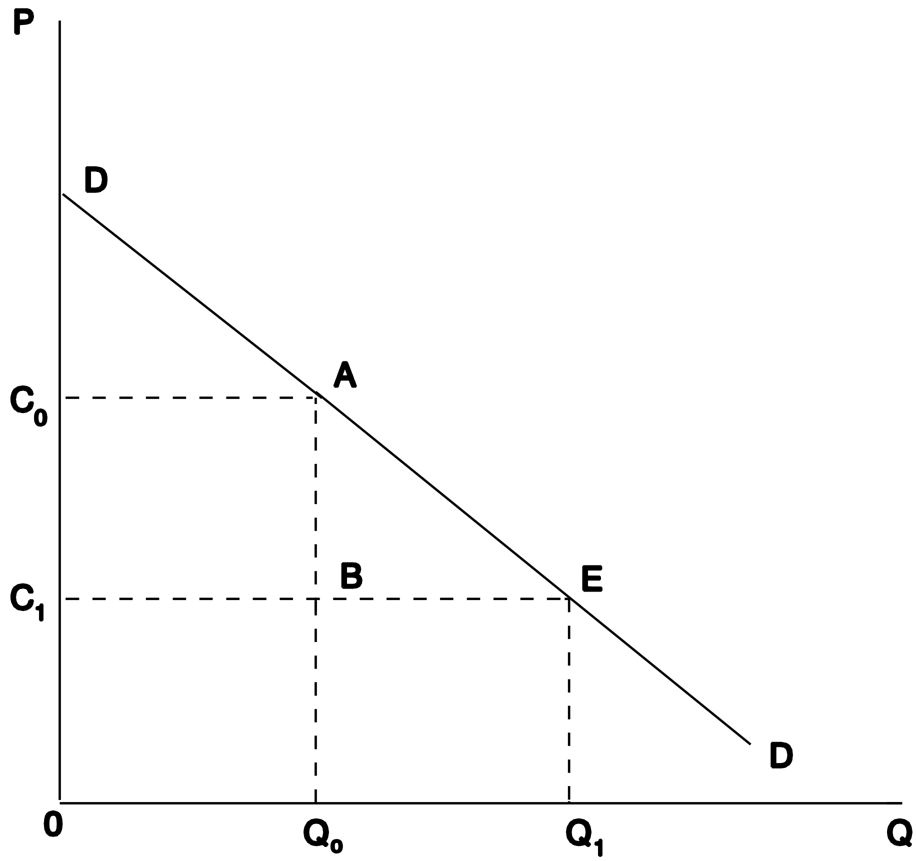

Figure 4
Factors Conditioning Tradeoffs Between Stronger and Weaker Patent Protection

Contributors to
Likelihood That Protection is Too Strong

1. A relatively large number of potential innovators (could lead to wasteful pre-patent competition).
2. Market power enjoyed by innovators (facilitates high price-cost markups on innovation). Welfare losses exacerbated if innovator is a foreigner.
3. Directions for technological change are unclear and licensing is difficult (may render "monopoly" development of new technology inefficient).
4. Government is relatively large funder of R&D (rents generated by patents may be unnecessary).

Contributors to
Likelihood That Protection is Too Weak

1. Limited ability to appropriate benefits of new technology (patent protection may be the only viable way to ensure adequate rate-of-return to innovations).
2. Many potential follower firms with opportunities for "modest" technological improvements (could lead to wasteful post-patent competition).
3. Strong intellectual property protection elsewhere (could lead to retaliation by trading partners).