Intellectual Property Rights and the Future of Plant Breeding in Canada

A Thesis

Submitted to the College of Graduate Studies and Research

In Partial Fulfillment of the Requirements

For the Degree of Doctor of Philosophy

In the Department of Bioresource Policy, Business and Economics

University of Saskatchewan

by

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PERMISSION TO USE

ABSTRACT

Canada has a long history of investing in agricultural research, with public funds playing a dominant role for most crops up until recently. With the advent of biotechnology in the 1980s, the research industry underwent significant transformations. Crops more amenable to the application of DNA modification techniques (e.g., canola) gained considerable attention by the private sector and experienced an influx of private R&D investment and proliferation of intellectual property rights (IPRs). IPRs have changed the nature of knowledge from being non-excludable to being excludable, thus affecting the nature of research benefits and research incentives. The advantages and disadvantages of a stronger IPR system in Canadian agriculture are currently hotly debated in policy circles.

This thesis develops a theoretical model that describes the incentives for innovation and the distribution of benefits from research when such innovations are protected by Plant Breeders' Rights (PBRs) versus patents. Specifically, the research industry is modeled as a monopolistic seed company undertaking research, developing a new variety and selling it to heterogeneous farmers. The difference between PBRs and patents is embodied in the farmers' decision that incorporates the possibility of seed saving envisioned by PBRs, but not by patents. The simulation results show that under certain conditions PBRs can be as effective as patents in encouraging R&D activity, and that the share of farmers in total benefits is generally smaller under patents than under PBRs. The benefits under patenting regime, however, are not necessarily smaller in absolute terms.

This dissertation also develops a game theoretic model to study the impact of IPRs on the sharing of research inputs. The results reveal that when two private firms compete in a differentiated product market, they will have an incentive to protect their technologies and maintain exclusive rights. Therefore, sharing within private industry may be a challenge. As IPRs proliferate, however, a lack of incentive to share/cross-license may not be confined to private industry. IPRs may also impact the propensity of public researchers to protect or share their technologies.

To address the issue of sharing and assess the efficiency of the current IP protection system in the Canadian plant breeding industry, interviews with wheat and canola breeders were conducted. The responses suggest that, in general, patents have become more prevalent in

both industries over the last decade, which has, in turn, reduced germplasm and information flows and increased secrecy. There is also evidence that patents undermine R&D efforts in some potentially promising areas of research and make freedom to operate in the breeding industry a concern.

ACKNOWLEDGEMENTS

This study represents the culmination of four years of study and research. I would like to thank Dr. Richard Gray who not only served as my supervisor but also encouraged, guided and challenged me throughout writing of this dissertation. I am also thankful to my supervisor for his enthusiasm and faith in my capabilities.

I would also like to extend my appreciation to the member of my advisory committee Dr. Murray Fulton. He has not only provided his invaluable comments, but also was patient enough to listen to me any time I needed expert advice and spent his time discussing various aspects of my dissertation. I thank Dr. Don Gilchrist and Peter Phillips for their participation as committee members and for their valuable comments. I am also grateful to Bonwoo Koo for serving as external examiner and for his insightful suggestions provided during the defense.

I am greatly indebted to Curtis Pozniak and Brian Rossnagel for their valuable comments in the process of developing the questionnaire for plant breeders. I am also thankful to all the breeders that agreed to participate in the survey.

I would also like to thank all the faculty, staff and graduate students for creating an enjoyable learning atmosphere in the Department of Bioresource Policy, Business and Economics.

I am thankful to Igor Riabchyk for his encouragement and understanding throughout my PhD program. I also wish to express my deep gratitude to my parents and my sister, Olga Galushko, for their love, motivation, support and interest they offered along the way.

Most importantly, I am eternally grateful to my son, Daniel Riabchyk, who has brightened the days with his smiles and served as a major inspiration in pursuing my career goals.

This dissertation is dedicated to my beloved son, Daniel Riabchyk.

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Chapter 1

INTRODUCTION

1.1 Problem statement

Crop research is different from many other R&D investments due to the self-reproducing nature of most crops. The self-reproducing nature of certain plants, combined with the possibility of easy imitation of new varieties, makes crop research output non-excludable. Historically, this public good feature of crop research has undermined the ability of innovators to capture the created value, which has led, in turn, to a lack of incentive for private industry to get involved in plant breeding and R&D. Recognizing this lack of private incentive, crop research is often publicly funded.

In Canada, crop research was once considered an integral part of national policy. Prior to 1980s the public sector performed almost 100% of formal plant breeding for cereals and oilseeds (GRAIN (2003b)). The funding and control of crop research, however, has changed over the last twenty years. Governments are re-prioritizing research investment and directing more dollars away from crop development research toward efforts seen as more novel, further up the value chain, or providing quick payoff (Meristem (2005b)). In some crops, such as canola, cuts in budget funding were compensated by an infusion of private investment, while in others producers have introduced research levies to supplement public research. Producers have stepped up and provided support through wheat and barley check-offs as an alternative source of research dollars. Crop research in Canada is now at a crossroad, and it is vital to determine the appropriate future research policy.

Publicly funded crop research has played an important role in establishing a strong and competitive agricultural sector in Canada. One success story is the development of the early maturing Marquis wheat, which is a parent of nearly every variety of wheat grown in Canada and was a starting point to establishing Western Canada's wheat economy (AAFC). As new races of rust and other diseases emerged agricultural research funds made it possible to incorporate resistance traits. Currently there are wheat varieties that can control almost all disease and pest concerns, such as common bunt, leaf and stem rust, sawfly, and others. Public breeding efforts in wheat have paid off in the form of increased yields and high grain quality, which has earned Canada a high standing in the international wheat market. Canadian wheat yields have increased about ten to fifteen percent over the past twenty years. In recent years, there has been a 0.5 percent increase in yield per year, which means that we should expect to see at least another five to six percent improvement in the coming decade (Meristem (2004)).

Another example of a research success is the creation of a strain of canola, a minor crop in 1960 but now the second largest crop in Canada, as a source of vegetable oil safe for human consumption (Forest (2008), Malla (2001)).

Studies that assess research investment value of publicly funded crop research in Canada reveal that research efforts have yielded considerable benefits to society in terms of yield and disease improvements. A range of independent studies shows a minimum ten-fold return on cereal development research (Meristem (2005a)). Guzel, Furtan, and Gray (2005) identified a minimum four-to-one return on investment for wheat breeding and twelve-to-one return for barley breeding. Thus, the historical contribution of public crop research to national economic development should not go unrecognized.

Changes in technology and legal frameworks, witnessed in the 1980s, significantly influenced crop research funding and culture. The use of DNA technologies in plant breeding allowed the development of new plant varieties at a faster pace and lower cost. Genomics also enabled the innovators to identify their seeds, thus making intellectual property (IP) protection feasible. In 1982, the Canadian Intellectual Property Office held that single-celled organisms and within-cell processes were a patentable subject matter, which allowed patent protection for genetically engineered plants. In 1990, Canada adopted the Plant Breeders' Right Act, which provided IP protection for crops. The net result of this extensive use of biotechnology and the legal changes has been a significant increase in crop IP protection.

The ability to protect IP invited participation from the industry, thus transforming parts of the Canadian seed industry. Private sector investment in plant breeding in Canada nearly tripled throughout 1987-2001, from $33.2 mln. in 1987 to $92.5 mln. in 2001 (AAFC (2004)). The developments in the breeding sectors, however, have not been uniform across different crops, with a majority of private investment targeted on a narrow range of industrial crops that can be protected by patents.

The canola sector is the best example of how changes in the technology and intellectual property rights (IPRs) have affected the seed industry. Work on canola started in the 1950s, and for the first thirty years the development of rapeseed was performed almost totally by the public sector. A research culture of freely sharing information carried well into the 1970s (Kneen (1992)). Research on nutritional characteristics of canola oil contributed to an expansion of global demand for canola that has become the third largest source of edible oil.

Beginning in the 1980s, the use of biotechnology allowed the delivery, integration, and expression of defined genes into plant cells. The possibility of applying patents and a growing farm demand for seed made the canola industry attractive to private investment. In the post-1986 period, ninty percent of the technologies were coming from the private sector (Gray, Malla, and Phillips (2006)). The presence of the private sector changed the structure and research environment in the canola breeding industry. Canola varieties were hybridized and their characteristics and the knowledge and processes used to achieve them were patented (Kneen (1992)).

Currently, the canola industry is characterized by an extensive application of biotechnology, a preponderance of the private sector supported by public researchers in developing germplasm and some other areas, and considerable IP protection for plant traits and breeding technologies. Wheat represents an ideal counter-example to the canola sector. In the wheat industry, breeding is performed primarily through conventional methods, almost all research is public and producer funded, and there is a limited (but growing) application of IPRs.

Until recently, the use of genetic engineering to improve wheat has been rather limited. Wheat was the last cereal to be genetically transformed, partly because the genom of wheat (a set of chromosomes) is very complex, thus making the improvement process by any method genetically challenging (Patnaik, Khurana (2001)). Costly genetic transformation combined with consumer resistance towards genetically modified (GM) wheat has made it an unattractive crop for private investment. Despite its importance, wheat has faced declining support from the public sector, which adds yet another dimension to an analysis of the future of the wheat economy in Western Canada.

Due to its importance on the global level, however, there is increasing interest in wheat from the private sector; wheat is starting to lose its orphan status (Jordan (2000)). Some biotechnology devices, such as molecular markers that allow an insertion of a gene into a plant, are finding more and more applications. Some private seed companies around the world are intensively working on the development of GM wheat varieties possessing novel characteristics. For example, a Western Australian company, Grain Biotech Australia, has successfully transformed wheat, and developed and patented three GM wheat varieties: the first variety contains resveratrol (an antioxidant in red wine that protects against cardiovascular disease); the second contains a transgene for salt tolerance; and the third contains a unique resistance gene to barley yellow dwarf virus (O'Neill (2003)). Thus, there is evidence that biotechnology in wheat is offering obvious benefits to human health and the environment. Given its potential to solve the world wheat problem through faster development of high-yielding and disease resistant wheat varieties, we are likely to witness in the near future an increasing application of biotechnology in wheat improvement, greater involvement of the private sector, and a larger scale use of IPRs.

As IPRs proliferate, the wheat industry faces new constraints and questions. Innovations in the seed industry, and the wheat sector in particular, build extensively on an existing stock of knowledge. When research is cumulative, assigning property rights to essential inputs separates the building blocks of research. Obtaining access to all necessary pieces of IP increases the costs of conducting research in public institutions. In some cases, putting all IPs together may become prohibitively costly if there is some form of protection on them, and this may shut out public researchers from potentially promising research areas.

Even if the wheat industry captures the interest of the private sector and follows patterns observed in the canola industry, there will always be certain aspects of research non-excludable in nature and, in which the involvement of private companies is not justified in terms of R&D expenditures and returns. Present and future governments must recognize the importance of public involvement with biotechnology and complement private sector research to ensure the continuation of the public goods research. Successive Canadian governments have invested greatly to build a strong research base, and it should be kept intact to ensure that the past achievements are not wasted and that farmers continue to have access to innovations at a reasonable cost. With all the changes in technologies and IPRs, an important question, then, concerns appropriate public research policy in a world of IP protection.

1.2 Objective of the study

Over the past decades in Canadian agriculture, some crops (e.g., canola) witnessed a rapid transition from publicly to privately financed research, while others, such as wheat and barley, are just starting to gain attention from the private industry. The presence of the private sector has changed the research environment, with IPRs becoming an important element in the research industry. Some crop research is jeopardized when public researchers face restrictions in accessing proprietary research inputs, while themselves becoming more concerned about protecting their IPs. For this reason, IPRs and the future of plant breeding in Canada should gain priority in public discussions.

The principal objective of this doctoral study is to develop a broader understanding of how intellectual property rights for biological materials change the research environment in the plant breeding industry and impact the distribution of research benefits. In particular, theoretical studies on IPRs in agriculture lack a detailed analysis of how farmers' exemption contained in the Plant Breeders' Rights Act (1990) makes the PBR-based IP protection system different from a patent-based one. This dissertation fills this gap by modelling the research and variety adoption process to study the incentives of a life-science company to undertake varietal development when plant varieties are protected by either PBRs or patents. As part of this issue, the analysis compares a farmer's welfare and the distribution of benefits under PBRs and patents.

In addition to analyzing the effect of IPRs on the seed sector, this study examines the impact of IPRs on the plant breeding community and the ability of breeders to carry out downstream research. More specifically, it explores the "tragedy of anticommons," secrecy, and dissemination of knowledge in the plant breeding industry in Canada. This includes gaining an understanding of freedom to operate issues (FTO) and working solutions to FTO.

Meeting these objectives should result in a richer framework for examining the economics of research and IPR policy, and bring to light problems in the breeding industry associated with the current IP protection system.

1.3 Methodology

Understanding the appropriate role of government in crop research in a changing IP environment requires an understanding of the R&D incentive structure under IPRs and their distributional effects.

To examine the economics of PBRs versus patents, this thesis models both the behaviour of a research firm within an imperfectly competitive framework and the behaviour of farmers. Specifically, the model is developed as a three-stage model, where the monopolistic seed company undertakes research and sells the new variety to heterogeneous farmers. In the first stage, the firm decides how much R&D effort to undertake, which determines the improvement of a new technology over a generic one (coming in the form of reduced costs or improved yields). In the second and third stages, farmers make adoption decisions and the research firm makes pricing decisions. In the second stage, given the varietal improvement and the seed price, farmers decide whether to adopt the new technology or postpone the adoption of the new technology until stage three. The choice of farmers depends on whether the technology is protected by PBRs or patents. For PBR-protected technology, purchasing the seed in stage two ensures a supply of one's own seed in stage three. In the third stage, non-adopting farmers decide whether to plant the new technology or continue seeding the generic variety. The model is solved for both PBRs and patents yielding the demand for seed, the seed price, and optimal innovation effort. Equilibrium solutions are used to derive a number of behavioural propositions.

A game theoretic model is used to examine the incentives for seed companies to share information in a world of IP protection. The model is set up in four stages. In the first stage firms choose whether to protect their technologies or not. In the second stage firms decide whether to license their technologies to rival research firms. Given the IP protection and licensing decisions firms decide how much to invest in variety development. In the final stage they compete on the market for new varieties. It is assumed that access to other firms' technology reduces the costs of varietal development and is, therefore, beneficial for the firm.

When a technology is patented each firm has a choice between licensing its technology to rivals or holding exclusive rights over it. Payoffs under cross-licensing, unilateral licensing, and exclusive rights are analyzed to arrive at an equilibrium outcome of the game and derive a number of behavioural propositions.

The results of a survey are employed to investigate the impact of IPRs on the breeding community. The canola sector represents a useful example where private investment has been increasing and IPRs have been proliferating over the last decades. The wheat sector serves as a counter-example: wheat research is still predominantly public and patents have not been used on as massive a scale as in the canola sector. Personal interviews with canola and wheat breeders are used to gain insight into the effect of IPRs on secrecy, the willingness of researchers to share research tool/germplasm, access to upstream technologies, dissemination of created knowledge, and freedom to operate.

1.4 Organization of the study

This thesis is organized into six chapters. A history of IPRs in agriculture, worldwide and in Canada in particular, is compiled and presented in Chapter 2. Chapter 3 develops the analytical framework used to derive a number of propositions on the key economic issues related to plant protection in the form of PBRs and patents. Implications for farmers' and innovators' welfare under the two regimes are also presented in this chapter. Chapter 4 provides a game theoretic approach to the tragedy of anticommons. Chapter 5 discusses the results of a survey of canola and wheat breeders, which provide the breeders' views on secrecy, germplasm flows, the "tragedy of anticommons," and efficiency of the current IP protection system in Canadian agriculture. Chapter 6 contains synopsis of the work, concluding comments, and lessons learned.

Chapter 2

PROTECTION OF PLANTS IN GLOBAL CONTEXT

2.1 Introduction

Innovation is important for sustainable long-term economic development. Continuous investment in the generation of knowledge is a prerequisite for maintaining a nation's scientific excellence, competitive advantage, and future economic growth (Scherer (1984), Romer (1990)). In this light, issues surrounding creation, dissemination, and protection of intellectual property (IP) arising from R&D are important. As discussed in Chapter 1, this dissertation deals with investment and IP in crop research.

Production of knowledge through R&D requires significant efforts in terms of time and money, and involvement of private firms is justified only if the returns to research can be appropriated. Appropriation of rents, however, is difficult when research output is concerned. Without properly defined ownership rights, it is not easy to exclude others from using the generated knowledge, which undermines the ability of innovators to capture the rents and leads to underinvestment in R&D. Intellectual property rights (IPRs) render knowledge excludable and promote innovative activity by providing the inventor with a temporary right over production and distribution of the innovation (Arrow (1962)).

Although the importance of IPRs as an innovation stimulus was recognized long ago, establishment of an IP protection system in *plant breeding* has faced a number of issues. First, granting ownership rights over plants is considered contrary to the acknowledgement of the contributions of indigenous communities in nourishing and maintaining biodiversity. Crop research is cumulative in nature and incorporates the traits from existing germplasm stock. New varieties of crops are developed using genetic material nourished by farmers over generations and should, therefore, be considered as part of indigenous knowledge rather than patentable inventions. Second, unlike other product innovations, open-pollinated plants can reproduce the traits bred in by the seed developer, which allows the technology to be adopted on a large scale without remunerating the innovator. When varieties of crops are created through a traditional selection process, not only do seeds self-reproduce, but it is difficult or impossible to distinguish varieties by looking at their seeds (Herdt (1999)). These two points make enforcement of IPRs extremely difficult and have been the main reason for a lack of private incentive to perform varietal development.

Where technology has created excludability, private research has been important. In some crops, such as maize, private firms employed hybridization techniques to make their innovations excludable. Due to the crossing of distinctly different genotypes, hybrids perform extremely well in the first year, but the traits are not maintained in subsequent generations. Hybridization provided a natural protection against the use of the technology for subsequent reproduction. As a result of this excludability, a large private research industry for corn has existed in the United States since 1960.

In some countries, a form of plant protection was available for a long time. In the United States, for example, the Plant Patent Act (1930) provided protection for vegetatively reproduced plants, and the Plant Variety Protection Act (1970) extended protection to plants reproduced by seeds. In Canada, the Seeds Act (1923) regulated the distribution of seeds by prohibiting sales of seed under a grade name, thus providing protection for seed developers similar to that of a trademark. While these limited property rights created private seed distribution industry, private breeding remained small relative to the public sector.

For non-hybrid crops, the application of molecular biology advances in plant breeding marked a new era in the protection of self-pollinated plants. Incorporation of specific genes into plant cells allowed identification of seeds. A means of distinguishing seeds allowed seed developers to exercise property rights over genetic material.

A seminal court decision in the United States, *Diamond vs Chakrabarty* (1980), paved the path for patenting of life forms, including plants. Canada followed suit in 1982, when the Canadian Patent Office held that single-celled organisms and within-cell processes were patentable, which offered patent protection for plants developed through DNA modification techniques. Following the plant-related American court decisions in the 1980s, a surge to strengthen plant protection spread over to Europe, Australia, Japan, and a number of developing countries.

IPRs are national in character and vary from country to country, thereby limiting the movement of genetic materials across national borders (Herdt (1999)). For this reason, a number of international agreements have been signed to harmonize IP protection worldwide. The two most important arrangements are the Convention of the International Union for the Protection of New Varieties of Plants (UPOV, 1961) and Trade-Related Intellectual Property Rights agreement (TRIPS, 1994). The UPOV system is a compromise between farmers' and breeders' interests. It gives plant breeders control over sales and reproduction of the developed varieties, while preserving farmers' rights to save the seed. The concept of farmers' rights was developed to reflect the contributions that traditional farmers, particularly in the developing world, have made to the preservation and improvement of plant genetic resources (Helfer (2002)).

As the system of IPRs has evolved some fears were expressed that privatization of biological resources can reduce biological diversity and lead to an exploitation of the biological flora of the resource rich countries. Some international conventions (e.g., the Convention on Biological Diversity, International Treaty on Plant Genetic Resources for Food and Agriculture) have been developed to mirror these concerns and specify the rights over indigenous germplasm.

As this dissertation deals with the economics of IPRs for plants in Canada, it is important to understand the international agreements for plant IP because they frame national legislation. Therefore, this chapter discusses international developments in the area of plant IP and presents an overview of the evolution of plant IP laws in various countries. Section 2.2 outlines the major international agreements that are meant to harmonize the IP laws worldwide. Section 2.3 describes how, in response to global developments and technological changes, individual countries (namely, the United States, Canada, Australia, and the European Union) changed their IP laws to incorporate plants and other living organisms. The chapter concludes with Section 2.4.

2.2 International Legislation to Protect IP in Agriculture

2.2.1 The International Union for the Protection of New Varieties of Plants (UPOV)

Prior to the mid-1960s, only a few countries allowed intellectual property protection for plants and animals. Seeds were exchanged between farmers and countries based on a belief that food security should not fall into the domain of commercial interests (Cullet (1999)). In Europe and North America, however, the principle of free access to information has grown increasingly restrictive due to pressure from the private sector for establishment of a system of private property rights (Cullet (1999)). In the early 1960s, a number of western European countries addressed the issue of IP protection in agriculture, and these discussions served as the foundation for the International Union for the Protection of New Varieties of Plants.

The purpose of the UPOV was to recognize and grant rights to plant breeders on an internationally harmonized basis so as to encourage the development of new varieties for the benefit of society (UPOV (2002)). The UPOV Convention was first signed in 1961 and came into force on 10 August 1968. It was the first international legislation to provide a form of legal protection for plant varieties in western countries. As of October 2007, there were sixty-five UPOV member states (see Table 2.1).

The UPOV system is probably the best-known example of a *sui generis* system and it has proven to be an effective plant protection mechanism. Even though the UPOV convention was developed in the interests of plant breeders, it contains some provisions that help safeguard the interests of researchers and farmers, and it is these provisions that distinguish the UPOV system from any other patent system (Tripp et al (2007)). The "breeder's exemption" is the most important provision, stating that "the breeder's right shall not extend to (i) acts done privately and for non-commercial purpose; (ii) acts done for experimental purposes; (iii) acts done for the purpose of breeding other varieties" (Article 15, UPOV-1991). This is in contrast to the patent system, in which researchers cannot make use of a protected variety as a germplasm source.

To progressively strengthen plant breeders' rights and adapt to changing market conditions the UPOV convention has been revised a number of times - in 1972, 1978, and 1991

Table 2.1: *The 65 members of UPOV as of October 18, 2007*

Albania (1991 Act)	France (1978 Act)	Poland (1991 Act)
Argentina (1978 Act)	Germany (1991 Act)	Portugal (1978 Act)
Australia (1991 Act)	Hungary (1991 Act)	Republic of Korea (1991 Act)
Austria (1991 Act)	Iceland (1991 Act)	Republic of Moldova (1991 Act)
Azerbaijan (1991 Act)	Ireland (1978 Act)	Romania (1991 Act)
Belarus (1991 Act)	Israel (1991 Act)	Russian Federation (1991 Act)
Belgium (1961/1972 Act)[1]	Italy (1978 Act)	Singapore (1991 Act)
Bolivia (1978 Act)	Japan (1991 Act)	Slovakia (1978 Act)
Brazil (1978 Act)	Jordan (1991 Act)	Slovenia (1991 Act)
Bulgaria (1991 Act)	Kenya (1978 Act)	South Africa (1978 Act)
Canada (1978 Act)	Kyrgyzstan (1991 Act)	Spain (1961/1972 Act)
Chile (1978 Act)	Latvia (1991 Act)	Sweden (1991 Act)
China (1978 Act3)	Lithuania (1991 Act)	Switzerland (1978 Act)
Colombia (1978 Act)	Mexico (1978 Act)	Trinidad and Tobago (1978 Act)
Croatia (1991 Act)	Morocco (1991 Act)	Tunisia (1991 Act)
Czech Republic (1991 Act)	Netherlands (1991 Act)	Turkey (1991 Act)
Denmark (1991 Act)	New Zealand (1978 Act)	Ukraine (1978 Act)
Dominican Republic (1991 Act)	Nicaragua (1978 Act)	United Kingdom (1991 Act)
Ecuador (1978 Act)	Norway (1978 Act)	USA (1991 Act)[2]
Estonia (1991 Act)	Panama (1978 Act)	Uruguay (1978 Act)
EC (1991 Act)	Paraguay (1978 Act)	Uzbekistan (1991 Act)
Finland (1991 Act)		Viet Nam (1991 Act)

[1] - "1961/1972 Act" means the International Convention for the Protection of New Varieties of Plants of December 2, 1961, as amended by the Additional Act of November 10, 1972

[2] - With a reservation pursuant to Article 35(2) of the 1991 Act

Source: UPOV (2007)

(Cullet (2003)). The 1978 Act was in force until April 1998, when the 1991 revision was ratified by a sufficient number of participating countries.

All these revisions require that the variety should be novel, distinct, and stable to justify protection. UPOV-1978 states that a new variety must not have been offered for sale or marketed in the state in which the breeder applies for protection. The 1991 revision relaxes this provision by allowing the variety to be offered for sale for up to one year prior to the application date. It also extends rights to include importing, exporting, conditioning, and stocking the variety. Harvested materials and products made from harvested materials are also covered by PBRs. The 1991 UPOV convention introduced the idea of "essentially derived" varieties. A variety is considered an "essentially derived variety when... it is predominantly derived from the initial variety, while retaining the expression of the essential characteristics" (1991 Convention para. 14(5)(b)). UPOV-91 restricts the rights of researchers to use the protected variety for the development of new varieties. The holder of a PBR may limit the right of another breeder to produce, develop, and sell any variety that is essentially derived from the protected variety (GRAIN (1996)). In most cases, the permission to produce and sell the essentially derived variety would be granted for a royalty fee (Lesser (1997)).

Under UPOV-1978, the protection was granted for a period of a minimum fifteen years for all plants except vines and trees, for which protection was provided for a minimum of eighteen years. UPOV-1991 extends the PBR length to twenty years and twenty-five years, respectively (UPOV-1991, Art. 19). While UPOV-1972 and UPOV-1978 conventions explicitly stated that double protection (i.e., the use of patents and plant breeders certificates) was not allowed, the 1991 revision eliminated the double protection ban, althought the member-states may prohibit double protection by their national laws (Cullet (2003)).

As the UPOV system was being adapted to economic conditions, some changes were made with respect to the "farmer's privilege" provision. Under the first two revisions of the UPOV convention, farmers were given an automatic right to save and re-plant the seed from a protected variety without authorization from the breeder, as well as share the seed with other farmers. In the 1991 revision, this right was eliminated in the sense that the farmer's exemption is left to the discretion of the member states, which may allow farmers to save the seed of a protected variety for use on their own land plots, but it is no longer an automatic right (GRAIN (1996)). The new provisions allow for the possibility of re-using the protected seed only if farmers pay royalties to the breeder (GRAIN (1996)).

The experience from the UPOV system showed that it was successful in encouraging plant breeders' efforts and increasing the spectrum of new varieties available to farmers. Over 100,000 new varieties have been protected under the UPOV system since its introduction. Some 5,000 new varieties receive a grant of protection in UPOV member states each year (Greengrass (2000)).

2.2.2 Trade-Related Intellectual Property Rights (TRIPS)

TRIPS was the initiative of some developed countries, led by the United States, pressing for stronger protection of intellectual property worldwide. The results of the survey conducted by the U.S. International Trade Commission revealed that American firms were losing US$50 billion a year because of a lack of appropriate IP protection in the technology importing countries (Adede (2003)). That inspired discussions by Amercian industry representatives about IPRs within the General Agreement on Tariffs and Trade (GATT) framework, and the decision to include "Trade-Related Aspects of Intellectual Property Rights" on the agenda of the Uruguay Round in 1986. The basic assumption for the negotiation of the TRIPS agreement was encapsulated in the following statement (Correa (2007)):

Desiring to reduce distortions and impediments to international trade, and taking into account the need to promote effective and adequate protection of intellectual property rights, and to ensure that measures and procedures to enforce intellectual property rights do not themselves become barriers to legitimate trade (Correa (2007), p.1).

Intensive discussion regarding the commencement of negotiations on TRIPS continued between 1986 and 1989, but the real discussion on the TRIPS agreement began in March 1990. A couple months later, a group of twelve developing countries joined the negotiation process (Correa (2007)).

TRIPS allows for the availability of patents for inventions, either products or processes, in all fields of technology. Member countries have the liberty to "provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof" (Article 27.3.b). Thus, in terms of protection of plant genetic resources, TRIPS gives some scope in designing a plant protection system. It should be noted that protection should be available for *plant varieties*, while patentability of *all plants* is not required. Because TRIPS does not provide a definition of a "plant variety," the interpretation differs among countries, which has complicated the implementation of the TRIPS (Ragavan (2007)).

The further flexibility of Art. 27.3 relates to its use of the expression "an effective *sui generis* system." The agreement does not specify the constituents of the effective *sui generis* plant protection system and allows individual countries to choose from available alternatives.

Thus, TRIPS does not harmonize plant variety protection, but merely requires that one of the article's broad forms of protection covers plant varieties (Ragavan (2007)).

As a minimum standard required by TRIPS, the UPOV-based mechanism has been applied by many countries to provide plant variety protection. Ragavan (2007), however, puts forward a number of arguments discussed below as to why it was not the original intent of TRIPS to designate the UPOV system as an effective protection regime. First, when the parties were negotiating TRIPS, the UPOV-1978 was in place, but at the same time it was not explicitly mentioned in the agreement. While TRIPS allowed for the combination of patents and *sui generis* systems to protect plants, UPOV-78 admitted only one form of protection for the same botanical species either a patent or breeder's right, but not both. This inconsistency implies that initially, when TRIPS was negotiated, UPOV was not considered an appropriate or effective mechanism for plant protection. Second, UPOV cannot be viewed as an *"effective"* regime for plant protection because of diluted eligibility requirements. UPOV grants breeders' rights on new, distinct, uniform, and stable varieties. The term "new" means that the variety has not been sold or otherwise disposed of to others, but does not preclude breeders from making superficial innovations. In other words, the eligibility requirements imply that the breeder can obtain a right over varieties that are only minor modifications of common knowledge. Breeders may, in essence, monopolize the genetic material from the public domain and protect such material as a premium innovation (Ragavan (2007)). Thus, UPOV seems unable to differentiate between genuine creativity in plant breeding and mere appropriation of public resources that may undermine a nation's genetic diversity. These loopholes demonstrate UPOV's inability to be "an effective *sui generis* system" as required under TRIPS (Ragavan (2007)).

At the initial stage of negotiations, protection of plants by means of PBRs as an effective *sui generis* mechanism was not approved by some World Trade Organization (WTO) members. For example, during the TRIPS negotiations, the United States insisted on providing patent protection for plants, while Japan claimed that PBRs did not fulfill their primary role of encouraging innovation in agriculture (Ragavan (2007)). A number of WTO members have tried to tighten the IPRs regime since TRIPS' conclusion and are now parties to TRIPS-plus agreements (Ho (2007)). These are bilateral or regional agreements that specify protection beyond the minimum standards provided by TRIPS. Such agreements are being negotiated by the United States, the European Union, and the European Free Trade Association (EFTA), which includes Switzerland, Iceland, Norway, and Liechtenstein. Recently, several European countries have been negotiating bilateral agreements with developing countries to strengthen plant protection, claiming that the current TRIPS framework gives the latter group too much flexibility in terms of protecting life forms (Berne Declaration (2004)).

As described in the Berne Declaration (2004), the EFTA's TRIPS-plus agreements have four main elements. First, while the TRIPS agreement does not make any reference to the UPOV system, the TRIPS-plus treaties force the developing countries to implement UPOV-1991, which is more restrictive than UPOV-1978 in terms of breeders' and farmers' rights. Even though most bilateral agreements have allowed the implementation of either UPOV-78 or UPOV-91, it is likely that the countries that are not yet members of UPOV will only be allowed to adopt the latest revision (i.e., UPOV-91) upon their accession. Second, the developing countries are required to join the Budapest Treaty, which facilitates patenting life forms by allowing a physical deposit of a sample of a microorganism as proof of the invention for the purpose of patent protection. Third, TRIPS-plus forces developing countries to grant patent protection for biotechnological inventions, thus opening the doors for large multinational companies engaged in genetic engineering. Fourth, compliance with the "highest international standards" is required for developing countries, which implies that the developing world has to employ the IPRs regimes of the industrialized nations. As of June 2007, the EFTA States have concluded fifteen free trade agreements with a total of nineteen partner countries and territories around the world, namely: Chile, Croatia, Egypt, Israel, Jordan, the Republic of Korea, Lebanon, Macedonia, Mexico, Morocco, the Palestinian Authority, Singapore, the Southern African Customs Union (SACU comprising Botswana, Lesotho, Namibia, South Africa and Swaziland), Tunisia, and Turkey (EFTA (2007)). Table 2.2 lists the agreements concluded or presently being negotiated between the EFTA states and developing countries, and the IPRs requirements in the field of plant protection.

Table 2.2: Plant-related TRIPS-plus provisions of EFTA-States agreements with the developing countries

EFTA Partner Country (Status of the Agreement)	**TRIPS-Plus Provisions**
Chile (Signed on June 26, 2003)	Must join UPOV by 1 January 2007 and Budapest by 1 January 2009; must ensure *"adequate and effective patent protection for inventions in all fields of technology"; enhanced protection of undisclosed information*
Croatia (Signed June 21, 2001; entry into force April 1 2002)	Must join UPOV-61 by January 1 2003; ensure *"adequate and effective patent protection for inventions in all fields of technology on a level similar to the protection prevailing in the European Patent Convention of 5 October 1973, as well as additional protection of up to five years before 1 January 2004 for plant protection products"*
Egypt (Signed January 27, 2007)	Must join UPOV-78 or UPOV-91 and Budapest Treaty by the end of the fourth year after the entry into force; must ensure *"patent protection for all fields of technology corresponding at least to the one in the TRIPS Agreement"*
Cooperation Council for the Arab States of the Gulf (GCC) (Negotiations started in 2005 and are still ongoing)	Not yet known
Israel (Signed September 17, 1992; in force since January 1, 1993)	Must ensure *"adequate and effective legal protection of patents on a basis similar to that prevailing in the European Free Trade Area"*
Jordan (Signed on 21 June 2001; in force since 1 September 2002)	Must join UPOV and Budapest by 1 January 2006; must ensure *"adequate and effective patent protection for inventions in all fields of technology on a level similar to that prevailing in the European Patent Convention"*
Lebanon (Signed 24 June 2004)	Must join TRIPS, Budapest and UPOV by 1 March 2008. Lebanon shall ensure *"protection on a level corresponding to the one in the TRIPS Agreement"*. Enhanced protection of undisclosed information
Macedonia (Signed June 19, 2000; in force since May 2, 2002)	Must join the Budapest Treaty by January 1, 2001 and UPOV by January 1, 2002; must ensure *adequate and effective patent protection for inventions in all fields of technology on a level similar to that prevailing in the European Patent Convention of 5 October 1973, as well as, before 1 January 2002, additional protection of up to five years for pharmaceutical and plant protection products"*

Continued on Next Page...

Table 2.2 – Continued

EFTA Partner Country (Status of the Agreement)	**TRIPS-Plus Provisions**
Mexico (Signed on 30 November 2000; in force since 1 July 2002)	Must join UPOV and Budapest by 1 January 2002
Morocco (Signed on 19 June 1997; in force since 1 December 1999)	Must join UPOV and Budapest by 1 January 2000; must ensure *"adequate and effective patent protection for inventions in all fields of technology on a level similar to that prevailing in the European Patent Convention"*
Palestinian Authority (Signed on 30 November 1998; in force since 1 July 1999)	*"Shall grant and ensure adequate and effective protection of intellectual property rights in accordance with the highest international standards"*
Singapore (Signed June 26, 2002; in force since January 1, 2003)	Must ensure *"adequate and effective patent protection for inventions in all fields of technology…on a level corresponding to Articles 52 through 57 of the European Patent Convention"*
South African Customs Union (SACU) (Signed June 26, 2006)	The Parties grant and ensure adequate, effective and non-discriminatory protection of intellectual property rights. Review clause
Tunisia (Signed December 17, 2004; in force since 2005/2006)	Must join UPOV-78 or UPOV-91 and the Budapest Treaty by 2010; ensure *"adequate and effective patent protection for inventions in all fields of technology"*; may exclude from patentability *"plant and animal varieties other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes"*
Turkey (Signed December 10, 1991; in force since April 1, 1992)	Must join Budapest Treaty and UPOV by January 1, 1999; must ensure *"adequate and effective patent protection for inventions in all fields of technology on a level similar to the one prevailing on 2 May 1992 in the states members of the European Patent Convention. Patents must be available and patent rights enjoyable without discrimination as to the place of invention and the field of technology"*

Source: Compiled by the author from EFTA (2007)

A number of free trade agreements (FTAs) outlining IPR policies in the participating countries have been signed by the United States. On 24 October 2000, the United States reached an agreement with Jordan that came into force in December 2001 (Roffe (2004)). By 2006, the United States concluded free trade agreements with Israel, Australia, Morocco, Jordan, Singapore, Chile, Bahrain, and Central American countries (CAFTA)(USTR (2007)).

The TRIPS-plus provisions of these agreements related to protection of plants are provided in Table 2.3. Currently, the United States is negotiating similar agreements with Thailand, Malaysia, and the Southern African Customs Union (SACU). These free trade agreements indicate that the United States has tried to establish much stronger IPRs regimes in the developing countries than those provided for by the EFTA states' agreements. The accession to UPOV-91 is mandatory for all parties of these agreements, while many of the agreements further state that the contracting parties must undertake efforts to make *patent* protection for plants available.

Some observers believe that the United States was the initiator of the TRIPS-plus agreements. However, the EU long preceded the United States in implementing the TRIPS-plus agenda through its bilateral model of Association Agreements (AA), hence pioneering the creation of the TRIPS-plus model globally (Said (2007)). The EU has forced TRIPS-plus commitments regarding intellectual property on life forms in almost ninety developing countries (GRAIN (2003a)). Like the American and EFTA free trade agreements, the bilateral agreements of the EU are aimed at reducing the differences between plant protection in Europe and the developing world. Under some agreements, accession to UPOV and the Budapest Treaty is mandatory for the contracting parties, while some agreements state that IP protection of life forms must be compatible with the highest international standards (GRAIN (2003a)).

At the very beginning, when the developed nations tried to promote IPRs, their main argument was that stronger IPRs would increase research and benefit the developing countries' agriculture and food security by opening up access to superior technologies. Developing countries (the South), however, were skeptical about the proclaimed benefits of IPRs. On the one hand, the South was concerned about the farming community. Privatization of the seed sector would make farmers dependent on seed supplies from industrial sources. Because a majority of farmers in the developing world are subsistence farmers, paying for seeds would undermine their ability to produce food at a reasonable cost. On the other hand, there were growing concerns about the effect of privatization on developing countries' biodiversity. That IPRs encouraged innovation also meant that they opened new paths for bioprospecting and the utilization of traditional knowledge. The developed nations accessed genetic material

Table 2.3: *The US Free Trade Agreements and TRIPS-plus provisions in the area of plant protection*

US Partner Country (Status of the Agreement)	**TRIPS-Plus Provisions**
Jordan (Signed October 24, 2000)	UPOV-91 shall be a minimum level of plant protection; must ensure that *"patents are available for any invention, whether product or process, in all fields of technology, provided that it is new, involves an inventive step and is capable of industrial application*"; may exclude from patentability inventions protection of which contradicts *ordre public;* must be a party to the Budapest Treaty
Chile (Entered into force January 1, 2004)	Must accede UPOV-91 (currently it is a member of UPOV-78) by January 1, 2009; *"shall undertake reasonable efforts to develop and propose legislation within 4 years from the entry into force of this Agreement that makes available patent protection for plants that are new, involve an inventive step, and are capable of industrial application"*
Singapore (Signed January 15, 2003)	UPOV-91 shall be a minimum level of plant protection; "*may exclude inventions from patentability only as defined in Articles 27.2 and 27.3(a) of the TRIPS Agreement"*
Australia (Concluded February 8, 2004)	Must be a party to the Budapest Treaty and UPOV-91; must ensure that *"patents are available for any invention, whether product or process, in all fields of technology, provided that it is new, involves an inventive step and is capable of industrial application*"; may exclude from patentability inventions protection of which contradicts *ordre public;* "*parties shall endeavour to reduce differences in law and practice between their respective IPRs systems"*
Morocco (Concluded in March 2004)	Must accede UPOV-91; *"each Party may only exclude from patentability inventions, the prevention within its territory of the commercial exploitation of which is necessary to protect ordre public or morality";* must ensure that patents are available for plants and animals;
CAFTA-DR[1] (Signed August 2, 2005)	Must accede the Budapest Treaty by January 1, 2006 and join UPOV-91 by January 1, 2008; *"any Party that does not provide patent protection for plants by the date of entry into force of this Agreement shall undertake all reasonable efforts to make such patent protection available"*
Bahrain (Concluded in May 2004)	Must join UPOV-91 and the Budapest Treaty; *"each Party shall make patents available for plant inventions"*
Peru (Signed April 12, 2006)	Must be a party the Budapest Treaty and join UPOV-91 by January 1, 2008; *"a Party that does not provide patent protection for plants by the date of entry into force of this Agreement shall undertake all reasonable efforts to make such patent protection available"*

[1] – Dominican Republic – Central America – United States

Source: Compiled by the author from USTR (2007)

Table 2.4: *Bilateral TRIPS-plus provisions of the EU*

EU Partner Country (Status of the Agreement)	**TRIPS-Plus Provisions**
Africa-Caribbean Pacific countries (Signed in 2000)	The parties recognize the need to ensure adequate and effective protection of patents on plant varieties and on biotechnological inventions.
Algeria (Signed in 2002)	Algeria shall accede to and implement UPOV (1991 Act) within 5 years of entry into force, although accession can be replaced by implementation of an effective *sui generis* system if both parties agree. Must accede to Budapest Treaty
Bangladesh (Signed in 2001)	Bangladesh shall endeavour to join UPOV (1991 Act) and to accede to the Budapest Treaty by 2006
Lebanon (Signed in 2002)	Lebanon must join UPOV (1991 Act) and accede to Budapest Treaty by 2008
Mexico (Signed in 2000)	Mexico must accede to Budapest Treaty within three years and shall provide "highest international standards" of IPR protection
Morocco (Signed in 2000)	Morocco must join UPOV (1991 Act) and accede to Budapest Treaty by 2004
Palestinian Authority (Signed in 1997)	"Highest international standards"
South Africa (Signed in 1999)	South Africa shall ensure adequate and effective protection for patents on biotechnological inventions. "Highest international standards"
Sri Lanka (Signed in 1995)	"Highest international standards"
Tunisia (Signed in 1998)	Tunisia must join UPOV (1991 Act) and accede to Budapest Treaty by 2002. "Highest international standards"

Source: GRAIN (2003)

found in the developing world, made minor modifications, applied patents, and then exported the proprietary "new technology" back to the developing countries. This triggered debate between users (North) and providers (South) of biological resources, the heart of which was the perception of a misuse of biodiversity and indigenous knowledge nourished by farmers for generations. The cases where the developed world misappropriated the developing countries' indigenous knowledge are many, and one prominent example is presented in Box 2.1.

Developing countries questioned the legitimacy of using genetic resources without prior consent and benefit sharing. Illegal appropriation of traditional knowledge by developed nations has created an incentive for resource rich countries to protect their flora and fauna. Their attempts to develop laws for access and use of biological resources are reflected in the creation of international agreements, such as the Convention on Biological Diversity and the International Undertaking on Plant Genetic Resources.

2.2.3 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was a natural response to the human-induced loss of biodiversity worldwide, which became a real concern for most nations in late 1980s. The convention was opened for signatures on 5 June 1992, during the United Nations' conference on environment and development; by mid-December 1993, 167 countries had signed (CIESIN (1996)). It went into force on 29 December 1993. Currently, there are 190 parties to the CBD, while the United States, a major user of biodiversity worldwide, remains in opposition to the convention (CBD (2008)).

The objective of the CBD was the adoption of a treaty promoting the conservation of biological diversity, and the sustainable use of biological components (Scalise and Nugent (1995), Art. 1 of the convention). An important aspect of the convention was addressing the issue of intellectual property rights related to biological resources. Because the world's biodiversity has always been in the public domain, access has traditionally been open. It was perceived that existence of intellectual property rights to products developed from freely available genetic resources allowed research corporations in developed countries to extract substantial benefits. As most genetic materials used in research originated in developing countries, it was believed that the biological resources of developing countries were "exploited"

Box 2.1. Basmati Rice: the battle over genetic heritage[a]

A prominent example of misappropriation of developing countries' genetic diversity by the industrialized world is Basmati rice. Rice is the most important grain in Asia's agriculture and it accounts for about eighty percent of daily calorie intake (Primal Seeds (2007)). Over the centuries, a great deal of effort has been invested in rice breeding programmes, resulting in the development of a special kind of rice known as Basmati. Basmati rice is known for its unique aroma and flavour, and it has special value for indigenous communities in Asia. There are twenty-seven varieties of Basmati grown in India (Primal Seeds (2007)).

Transnational corporation RiceTec crossed farmers' varieties of Basmati rice with semi-dwarf varieties to obtain a "new line" of rice. RiceTec claimed that the new variety was an invention because it was suitable for production under a broader range of soil and climate conditions, while Basmati rice proved successful only in northern regions of India and Pakistan. In 1997, the U.S. Patent and Trademark Office (USPTO) granted a patent to RiceTec that covered twenty far-reaching Basmati claims (Shiva (2001)). The original patent specification claimed the development of "novel rice lines whose plants are semi-dwarf in stature, substantially photoperiod insensitive and high yielding, and produce rice grains having characteristics similar or superior to those of good quality Basmati rice" (Taubman (2007)). The patent gave the company the right to sell the "new" variety in the United States and abroad and was extended to "functionally equivalents", implying that others selling Basmati rice could be restricted by the patent. RiceTec would have sole right to use the term "Basmati" for marketing the rice anywhere in the world (Primal Seeds (2007)).

For Indian farmers, the patent on Basmati rice meant that they would lose control over and pay royalties for seeds that they had been breeding and growing for generations. The response to the RiceTec patenting was vigorous. In 1998, the Research Foundation for Science Technology and Ecology (RFSTE) at Delhi along with others, filed a case in public interest in the Supreme Court of India. Two years later, in response to public pressure, the government of India filed a request for re-examination of the patent granted by the USPTO, claiming that it violated the rights of Indian farmers who had been nourishing Basmati. Through the Agricultural and Processed Food Products Export Development Authority, the Indian government challenged some claims of the patent, successfully rescinding four out of twenty claims (Shiva (2001)). This preserved the interests of Indian exporters, even as the remaining sixteen claims still undermined the rights of Indian farmers to use Basmati seeds and plants. Unsatisfied with government attempts to fight for farmers' rights, the Research Foundation, along with other citizen groups, launched a global campaign against RiceTec's Basmati patents (Shiva (2001)). Eventually, the USPTO struck from the patent seventeen out of twenty claims, although the United States government insisted that it would never drop its generic claim to Basmati (Berne Declaration (2001)).

[a] *Source:* Compiled by the author from Shiva (2001), Primal Seeds (2007), Taubman (2007)

without proper acknowledgment of their contribution (see Box 2.1). To deal with this issue, the treaty obliges the contracting parties to fairly and equitably share "the benefits arising out of the utilization of genetic resources."

The CBD also addresses access to genetic resources, access to and transfer of technology, and handling of biotechnology and distribution of its benefits. It entitles governments of the signatory nations to rights to control physical access to biodiversity by enacting suitable legislation. The convention specifies that prior informed consent from the resource providing country is required to access genetic resources, and, thus, any use of the genetic material without this consent would constitute a violation of the CBD.

Under the convention, the contracting parties should attempt to create conditions "to facilitate access to genetic resources for environmentally sound uses by other Contracting Parties" (Art.16). In exchange, the nations utilizing the genetic resources of others in research should undertake legislative measures to ensure that research is carried out with the full participation of the contracting parties, and that benefits arising from commercial and other uses of those genetic resources are equitably shared with the country of origin. Thus, by allocating a portion of benefits derived from the use of genetic resources to the country of origin, the convention assigns property rights to naturally occurring genetic material to the source country. Article 19 states that not only the benefits should be shared, but the research results as well, which means that the discoveries should be disclosed to the country providing the genetic material.

The legislative response to the CBD convention has varied from country to country. As of 2003, only a few countries, such as the Philippines, Brazil, Costa Rica, India, and Andean Pact signatories (Bolivia, Columbia, Ecuador, Peru and Venezuela), have enacted regulations in response to the CBD mandate (Davalos et al (2003)).

The Philippines was the first country that adopted legislation in line with the CBD. Executive Order 247, implemented in 1995 restricted access to genetic resources (Safrin (2004)). The order recognizes that wildlife is under the state's control and supervision. In order to gain access to the material, a bioprospector has to go through multiple layers of national government review and consent (Safrin (2004)). Prior to applying for approval from the national government, the bioprospector must obtain written consent from indigenous communities, local offices, and from any affected private landowner. The procedure for obtaining consent at the local level varies, depending on whether an academic research or commercial research agreement is being sought. An interesting point is that these research agreements specify that any technologies developed from a biological resource originating in the Philippines are to be made available to a designated Philippine institution and can be used for commercial or local use without paying royalty (Glowka (1997)).

The Andean Pact countries, by adopting Decision 391, "The Common System on Access to Genetic Resources" (CSAGR), in July 1996, were one of the first in the world to standardize the laws regulating access to genetic resources across a region (Grajal (1999)). Under the CSAGR, the national government either owns or exercises control over raw genetic material. To receive genetic material from an Andean Pact country, a researcher or institution must obtain permission from the national government and traditional communities, as well as sign an agreement specifying the benefits to be received by the country providing the material. Access to genetic materials is restricted not only for foreigners seeking to obtain the material, but also to local research institutions, and there is no distinction between commercial or research use (Safrin (2004)).

To operationalize the provisions of the CBD, India enacted the Biological Diversity Act in December 2002 to control access to genetic resources in its territory (Biological Diversity Act (2002)). This Act provides for the establishment of a National Biodiversity Authority, State Biodiversity Boards, and Biodiversity Management Committees at the level of panchayats (village committees) and municipalities (Gadgil (2003)). To obtain a biological resource in the territory of India or knowledge associated with the resource for research, commercial utilization, or bio-survey, a foreign researcher or institution must obtain approval from India's National Biodiversity Authority. Transfer of the research results to any person who is not a resident of India is prohibited unless the Authority's consent has been received. The results, however, can be published or presented at any seminar or workshop. Approval from the Authority is also required if the researcher is seeking to apply intellectual property rights, both inside and outside the nation, to the product developed from any genetic material originating in India (Safrin (2004)). When granting an approval to patent the research outcome, the authority may impose conditions for benefit sharing.

Thus the CBD has inspired the resource rich countries to adopt legislative measures to control access to genetic resources, but unfortunately the current system has so far been characterized by a lack of international harmonization of access legislation, something necessary for facilitating access to biodiversity (Safrin (2004)). In general, the CBD and the laws that it inspired seem to be resulting in restricted access to genetic resources worldwide and, as a consequence, underutilization of those resources due to difficulties in obtaining necessary consents and approvals (Safrin (2004)). For example, since the adoption of the legislation in Philippines in 1995, as of October 2001 only two out of thirty-seven proposed projects have achieved all the necessary approvals (Safrin (2004)). It is becoming more difficult to obtain germplasm from countries such as China or the South American nations. It used to be quite easy to get genetic materials from Ethiopia or Kenya, but now most Third World countries are tightening up and monetary concerns are taking precedence (Salmon (2007)).

The CBD was the first international treaty that recognized the hitherto neglected elements of indigenous knowledge and biodiversity. It set certain rules under which genetic resources could be accessed, specifying that the resource-providing countries had the right to be remunerated. After signing the CBD, the issues of ownership of biodiversity and the compulsory compensation system were again raised by the Food and Agriculture Organization (FAO), and concluded with the International Treaty on Plant Genetic Resources for Food and Agriculture.

2.2.4 The International Treaty on Plant Genetic Resources for Food and Agriculture

During the 1980s, the FAO became concerned about firms in developed countries abusing the principle of free access to genetic resource collections. Before international treaties were signed, it was perceived that genetic resources were the heritage of humankind and, therefore, freely accessible. The developed countries were frequently criticized for holding most of the genetic resources that originated in the developing world and for allowing plant breeders to apply IPR protection for varieties developed from freely available materials.

Attempts to reconcile the interests of developing and developed countries in terms of access to and use of genetic resources, and to ensure sustainable use of genetic materials, concluded with the adoption of the International Undertaking on Plant Genetic Resources (IUPGR) in 1983. As of April 2008, 116 states were signatories to the IUPGR (Wikipedia (2008d)). The objectives of the Undertaking were "to ensure the safe conservation and promote the unrestricted availability and sustainable utilization of plant genetic resources for present and future generations, by providing a flexible framework for sharing the benefits and burdens" (FAO).

The developed countries were unsatisfied with the interpretation of "plant genetic resources" that included both unimproved and improved genetic material (Lesser (1998)). To exclude IPR-protected plant varieties and acknowledge the contribution of unnumbered generations of farmers who conserved, preserved, and made available plant genetic resources, the concept of "farmers' rights" was introduced into the IUPGR at the twenty-fifth session of the FAO conference in Rome in 1989. The resolution defined farmers' rights as "rights arising from the past, present and future contributions of farmers.... These rights are vested in the International Community, as trustee for present and future generations of farmers, for the purpose of ensuring full benefits to farmers, and supporting the continuation of their contributions" (FAO (1999)).

Some amendments in the IUPGR were needed to reflect changes in ownership and transfer of biological resources encouraged by the CBD and the TRIPS agreement. Negotiations to revise the IUPGR to harmonize it with the CBD started in 1994, and took seven years to reach an agreement. The Undertaking was finally converted into a legally binding agreement in November 2001, known as the International Treaty on Plant Genetic Resources for Food and Agriculture (IT). The treaty was put into force in 2004, and over one hundred countries have already ratified it (the United States, China, Japan, and Russia being notable exceptions). The first meeting of the governing body was held in 2006, where the standard material transfer agreement clause was adopted (Harvey (2007)).

The IT addresses three main issues: (1) access to genetic resources; (2) access to and transfer of the developed technologies; and (3) benefit sharing. The key feature of the treaty is a multilateral system (MLS) to be created to facilitate access to genetic resources used for research, breeding, and training purposes. The signatories to the IT must ensure that access to genetic resources in the multilateral system is expeditious and requires only minimal cost

(Harvey (2007)). To obtain biological materials, a standard material transfer agreement has to be signed. This agreement contains provisions covering the food uses only- not agricultural uses-of Annex 1 species. It allows the use of the material for breeding purposes, but does not permit application of intellectual property rights over the material. It should be mentioned, however, that the provisions regulating access to genetic resources are only applicable to the plant species specified in Annex 1, which covers only thirty-five food crops and twenty-nine forages selected on the basis of their importance for food security and the interdependence of countries in terms of their need to use the germplasm of those species (Seiler (2004)). Of the species covered by the treaty, about eighty percent of food is derived; most of the major crops are included, with soybeans a notable exception (Seiler (2004)).

The treaty obliges member countries to decide which materials under their jurisdiction will be placed in the MLS. Other agencies that are not member countries can also put materials into the system. Plant collections held by international institutions have played a central role in the formation of a multilateral system. The best example of this is the Consultative Group on International Agricultural Research. There are fifteen centres located around the world, and eleven of them have germplasm collections. They signed an agreement through the FAO in the 1990s to make their plant collections freely accessible, and have placed all their genetic resources under the auspices of the IT even though they don't belong to the member country. As of February 2007, Canada had plans to place in the MLS the Saskatoon seed repository, the Harrow clonal repository, and the Fredericton potato repository (Harvey (2007)).

The key part of the treaty is benefit sharing, which does not relate only to monetary benefits. Such aspects as information exchange, technology exchange, and assisting with capacity building, particularly in developing countries, make much more meaning. As for the access and transfer of the technologies, the IT specifies that if the technology were developed using biological material from the multilateral system, then it must be accessible and "technology transfer to developing countries will accordingly be promoted, although applicable intellectual property rights shall be recognized and effectively protected" (Art. 13).

Signing a standard material transfer agreement ensures that payment becomes possible. The standard material transfer agreement outlines the payment structure under the treaty (discussed below). The innovator may be obliged to make contributions if the product developed from genetic resources accessed under the multilateral system is commercialized. If the commercialized product has any limitations for further use in research and breeding, then payment is mandatory and accounts for 1.1% of sales of the product minus 30% of covered overhead costs. However, if the product is freely available for breeding and research purposes, then the payment is not triggered. A voluntary payment of 0.5% is also contained in a material transfer agreement. Voluntary payment applies regardless of whether the product is commercialized. When triggered, payments go to the global, pooled fund, not to the country of origin. These funds are earmarked specifically for germplasm conservation and capacity building, and are primarily available to developing countries (Harvey (2007)).

An important point of the IT to keep in mind is that if the material is obtained through the MLS and is partially developed without commercialization, and is then passed on to someone else, then the obligations under the SMTA are transferred to whomever receives that material.

To summarize, the IT is an attempt to create an atmosphere where germplasm exchange is facilitated and access costs are minimal, but compliance costs are high (Harvey (2007)). Compliance costs consist of accepting obligations to make freely available a product developed from the genetic material accessed under the system, or to make payments if restrictions are put on the product's research use. Payment arrangements do not mean much for breeders in Canada or other countries where higher life forms cannot be patented because the material protected by PBRs can be freely accessed under breeder exemption clauses. An important contribution of the treaty is to formalize the process of accessing biological resources. All plant breeders will be using standard material transfer agreements to access material from the gene banks in a year or two, and these agreements will provide proof of legal accession (Harvey (2007)).

2.3 Overview of Plant IP Protection Systems: International Experience

Section 2.2 reviewed the international agreements that regulate IP protection in plant breeding. Not only do these agreements mirror the interests of those countries that initiated them, but have also framed national plant protection legislation. The next section discusses how the national IP laws of some developed countries evolved in response to changes in the global plant protection regime and changes in technologies.

2.3.1 Plant Protection in USA

The United States was one of the first countries to take legal steps to protect new plant varieties. The first legislation that provided protection for new plant varieties was the Plant Patent Act (PPA) of 1930. Under the PPA act, only asexually reproduced plants were covered. Until recently, a plant patent prohibited selling or using the *whole* plant. However, 35 USC §163 has been amended in the most recent Congress so that the grant includes "the right to exclude others from asexually reproducing the plant, and from using, offering for sale, or selling the plant so reproduced, or any of its parts, throughout the United States, or from importing the plant so reproduced, or *any parts thereof* , into the United States" (Agris (1999)).

It should be mentioned that plant patents are associated with a broad "breeder's exemption". In the United States, for example, the court's ruling in *Imazio Nursery v. Dania Greenhouses* case (1995) indicated that infringement to the patent occurs only when the accused variety is actually derived *asexually* from the protected variety. Using the protected variety as a parent variety in a commercial plant breeding program would not constitute an infringement (Henson-Apollonio (2002)).

Decades later, after the introduction of the Plant Patent Act, protection was extended to sexually reproduced plants through the Plant Variety Protection (PVP) Act (1970). This act excluded fungi and bacteria, first generation hybrids, the seed, plants, celery, peppers, tomatoes, carrots, and cucumbers. The exclusion of the vegetable group was explained by the fact that these vegetables played an important role in household consumption, and there were growing concerns that protection of new vegetable varieties might cause a shortage of this group of vegetables and raise consumer prices (Strachan (2004)). In 1980, when the evidence had not supported the concerns about negative effects of plant protection, the 1970 Act was amended to exclude the vegetables from exceptions, so that only fungi and bacteria and first generation hybrids were exceptions to the PVP Act.

The amended version of the PVP included two special provisions: (1) a farmer's exemption; and (2) experimental exemption (PVPA, Sec. 113-114). According to the former, a farmer was permitted to save the seed from the protected variety for later use, for sale to others for something other than reproductive purposes, or for sale to other farmers for use as seed. The sale of harvested seed was granted only to a farmer or a third party acting on behalf of the farmer supplying the seed (*Delta & Pine Land Co. v. Peoples Gin Co.* (1983)). The experimental exemption allowed use of the protected variety for further research.

The protection afforded to new varieties under the PVP Act was strengthened in 1994, when the provision that allowed farmers to sell the saved seed was repealed. A legal battle followed and in January 1995, the United States Supreme Court limited the farmers' privilege to the quantity of seed that the farmer needed for his own sowing purposes, with permission to sell seed being limited to the unused surplus of the retained seed (Forge (2005)).

As for patenting plants, prior to the 1980s the USPTO did not permit patenting life forms, including plants and animals. Life forms were considered to be products of nature rather than human intervention, and were, therefore, not patentable (Bent et al (1987)). *Diamond v. Chakrabarty* (1980) paved the way for plants modified by both traditional breeding and molecular transformation to be covered by utility patents.

Bent et al (1987) discuss the contradictory decisions of the USPTO after 1980. A number of utility patents for plants, seeds, and plant tissue cultures were issued following *Chakrabarty*. In late 1984, the policy of the USPTO suddenly changed, with a number of pending applications rejected. It was claimed that as long as the claimed subject matter could be protected under the PVP or the PPA, the protection under the utility patent law (35 USC §101) was unavailable. The USPTO also asserted that granting several forms of protection for the same genus would violate Art. 2 of the 1978 UPOV Convention, which took effect in 1981 for plant patent applications and in 1983 for plant variety certification (Bent et al (1987)). It should be mentioned, however, that the 1978 revision of the UPOV Act contained an exception to Art. 2 (Art. 37), which placed the PVP into conformity with Convention requirements. Article 37 was designed specifically for the United States and it allowed different types of protection for the same species if such different protection forms were available prior to 31 October 1979. While all UPOV member states explicitly excluded plant and animal varieties from their patent laws, the United States did not change its patent law. According to Article 37 of the Convention, patenting of plants under 35 USC §101 was not a violation of the 1978 UPOV convention. Nevertheless, it was not until *Ex parte Hibberd* (1985), which related to maize cell lines, that plants became a patentable matter again. In *Ex parte Hibberd* , the PTO Board of Patent Appeals and Interferences concluded that the plant-specific laws were not intended to limit the scope of patentable subject matter under the general patent law (35 USC §101) (Bent et al (1987)). Thus, *Ex parte Hibberd* held that 35 USC §101 also encompassed plant material, which was protected under either the PPA or PVP. Since then, the United States and perhaps Japan have been the only countries to allow the inventor to protect a new variety through multiple means - the breeder can get the protection in the form of a certificate under the PVP or a patent under 35 USC §101 for the same species (Bent et al (1987)).

The decision of the USPTO Board of Patent Appeals and Interference served as the basis for subsequent court decisions and was never challenged until *J.E.M. Ag Supply v. Pioneer Hi-Bred* (2001). Approximately 1800 utility patents for plants were granted between *Hibberd* (1985) and *J.E.M. Ag Supply* (2001) (Sease (2007)). In *J.E.M. Ag Supply*, the illegal reseller of Pioneer Hi-Bred hybrid corn seeds, J.E.M. Ag Supply, Inc., claimed that the patent on hybrid corn was invalid because PVP was the exclusive statute for awarding protection to sexually reproduced plants and the patented seed did not fall within §101. In December 2001, the Supreme Court held that PVP did not place any restrictions on the subject matter under §101, nor did it contain any statement of exclusivity. Thus, the decision was that "newly developed plant breeds fall within the subject matter of §101, and neither the PPA nor the PVPA limits the scope of §101's coverage" (Cornell Law School (2008)).

The impact of the decisions in *Chakrabarty* and *Ex parte Hibberd* cases was tremendous. They opened a window of opportunities for developers of genetically modified plants, creating incentives for biotechnology industry to invest into the development of new gene traits and improved transformation tools. To further encourage investment by the biotechnology industry, in July 1993 the Senate passed the Biotechnology Process Patents Act, which came into force on 1 November 1995. The law defined the biotechnological process as (1) a process of genetically altering or otherwise inducing a single - or multi-celled organism to express an exogenous[1] nucleotide sequence, inhibit, eliminate, augment, or alter expression of an endogenous[2] nucleotide sequence, express a specific physiological characteristic not naturally associated with said organism; (2) cell fusion procedures yielding a cell line that expresses a specific protein, such as a monoclonal antibody; and (3) a method of using a product produced by a process defined by (1) or (2) or both (35 USC §103(b)).

From 1975 through 1998, 2,428 utility patents for biology-based agricultural technology were granted in the United States, of which 645 were assigned to universities and public institutions, 893 to small firms, start-up firms or individuals, and 955 to corporations. Of these patents, 536 covered transformation technologies, 1151 covered genetic traits, and 560 patents covered germplasm for maize, soybeans, and other plants (Taylor, Cayford (2002)). Barham et al (2002) used the United States Patent Office database to identify university-owned utility patents that were both agricultural and biotechnological. They point out that the number of agricultural biotechnology patents issued to universities in the four years from 1996 through 1999 (481) greatly exceeded the cumulative total of such patents issued in the previous twenty years (314) (Figure 2.1).

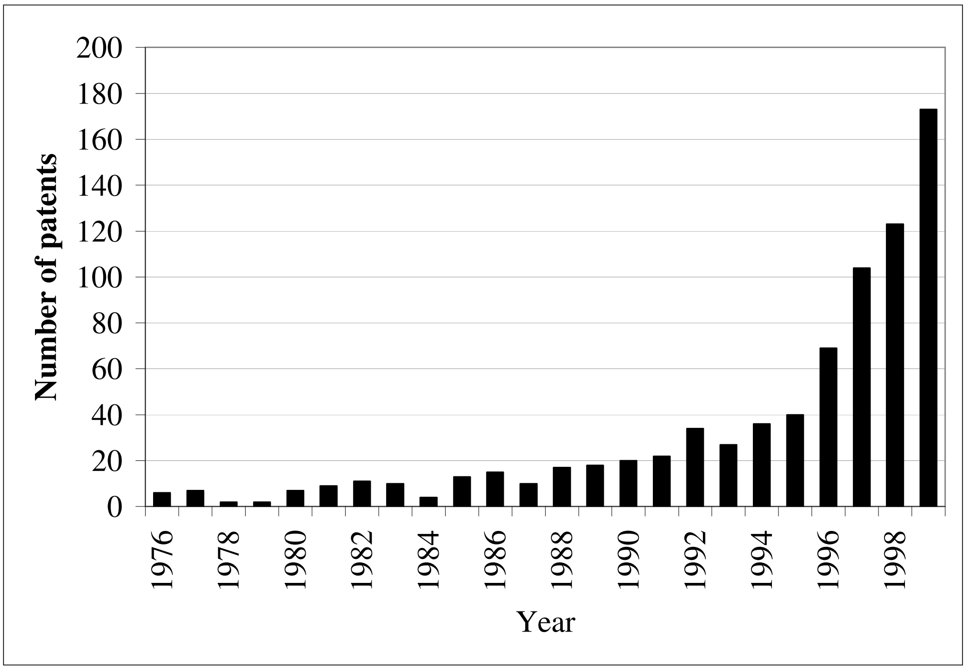
2.3.2 Plant Protection in the EU

Plant protection in the EU is characterized by the coexistence of national laws and a regional patent system intended to harmonize the patent application procedure. The chief mechanism for protecting plant IP in the EU is a UPOV-based system. It is coupled with the European Patent Convention (EPC), which regulates the patenting of inventions in the EU. Even though the EPC initially excluded IP in plant breeding, over time court decisions have reduced the scope of exemptions. These events are discussed in what follows.

Plant Breeders Rights

European countries were initiators of the UPOV. The United Kingdom, Germany, and the Netherlands were the first to ratify the 1961 UPOV Convention in 1968 and introduce PBRs to protect plants (Plantum NL (2008)). Joining the UPOV required European countries to adopt legislation consistent with requirements of the convention. In compliance with treaty obligations, the United Kingdom enacted the Plant Variety and Seeds Act (1964), with similar

[1] "Exogenous" means from another organism.
[2] "Endogenous" means originating from within the organism.



Source: Barham et al. (2001)

Figure 2.1: Agricultural biotechnology patents by US universities

legislation passed in the Netherlands, Denmark, and Germany (Wikipedia (2008b)).

Since the establishment of UPOV, all EU member states with the exception of Luxembourg, Greece, Malta, and Cyprus have joined UPOV (Blokland (2006)). As of 2007, sixteen EU members were signatories to UPOV-91, five to UPOV-78, and Belgium and Spain were implementing UPOV-61/72 (Blockland (2006), Wikipedia (2008b)).

Following the introduction of UPOV-91, the ways were thought to facilitate the PBR application process in multiple countries by providing a community-wide alternative to Plant Breeders' Rights. Efforts to achieve this concluded with EC Council Regulation 2100/94, which established a UPOV-91 based system for Community Plant Variety Rights (CPVR) (Byrne (2004)). Under this regulation, it is not possible to hold both a national right (whether a patent or a breeder's right) and a CPVR for one and the same plant variety. If a national right has been granted before a CPVR for the same variety, the national right will be suspended for the duration of the CPVR (Byrne (2004)).

The Community Plant Variety system has had a tremendous success among the EU member states. From April 1995 until February 2004, the Community Plant Variety Office received 16097 applications from EU countries. Forty-three percent were made by applicants from The Netherlands. Germany and France followed with eighteen and seventeen percent of the applications, respectively (Plantum NL (2008)).

European Patent Convention and Plant Patentability

Until now, the regional patent legislation for the European countries has been contained in the European Patent Convention (EPC), implemented in 1973 and revised on 13 December 2007. As of January 2008, the EPC had been ratified by thirty-four states. A single application may be filed to protect the invention in all thirty-four contracting states (Wikipedia (2008a)).

The convention specifies that in order to be patentable an invention must be "susceptible of industrial application, must be new and involve an inventive step" (Article 52). The convention contains some exceptions to the rules of patentability. In particular, it states that "plant or animal varieties or essentially biological processes for the production of plants or animals" are not patentable (Article 53(b)). Article 53(b), however, does not apply to microbiological processes or resulting products. The rationale behind the exclusion of plants and animals from the EPC was that the UPOV convention adopted in 1961 prohibited a double protection (Lightbourne (2005)).

At the end of the 1970s, there was strong pressure from the breeding community to amend the patent legislation in Europe to include plants and breeding methods (Van Overwalle (1999)). It was not until 1984 that IP protection with respect to plants became available under the EPC. The ruling of the Technical Board of Appeal of the EPO in *Ciba Geigy* (1984) determined that patent protection was extended to biological material. Ciba Geigy's claims were directed to propagating material treated with a chemical to give herbicide resistance to a plant. Although the examiner rejected the patent claims on the basis that they were directed to the "plant variety," which constituted an exclusion under Article 53(b), the Board of Appeal granted a patent to the inventor and held that chemically treating seeds did not create a new plant variety (Perdue (1999)).

Another Board of Appeal decision, T320/87 (*Lubrizol* , 1990), upheld the willingness of the European community to grant claims directed to plants. In *Lubrizol* , the Board ruled that the process for developing hybrids was patentable and that hybrid varieties did not fall within the category of "plant variety" because they did not constitute stable matter. These decisions stated that as long as a biological invention met patentability criteria and did not create a new plant variety, it was considered a patentable matter. Thus, according to the EPC, agricultural innovations could be patented only if proven that they do not relate to a specific variety (Santaniello (2000)).

Rapid development of the biotechnological industry required a legislative response on the part of the European Patent Organization (EPO). Even though biotechnological inventions satisfied the criteria for patentability, the interpretation of the EPC varied from country to country, which brought uncertainty and confusion regarding protection of transgenic plants via patents (Baggot (2000)). Patentability of transgenic plants was first considered in *Plant Genetic Systems* (PGS) (Decision T356/93). In 1990, the EPO granted a patent to PGS, which had claims to seeds, plants, and plant cells that were herbicide-resistant due to an insertion of a foreign nucleotide sequence into the plant's genom. In 1992, an opposition was filed by the Greenpeace organization on the ground that the claimed material constituted a "plant variety," and was therefore not patentable under Article 53(b). Because the term "plant variety" was not defined in the EPC, the Board of Appeal relied on the definition for "plant variety" provided in UPOV-91: "a plant grouping within a single botanical taxon of the lowest known rank, which grouping... can be distinguished from any other plant grouping by the expression of at least one of the said characteristics." Using this definition, the Board interpreted the claimed transgenic plant as a new plant variety and rejected the patent for a transgenic plant and cells when "contained in a plant" (Baggot (2000)). However, a patent was granted to transgenic plant cells and the transformation process because they were considered microbiological processes. Thus, this decision illustrated that, under the EPC, claims directed to genetically modified cells and the process of transferring the genetic material are patentable, whereas the developer cannot make claims to a transgenic plant itself.

In 1988, seeking to strengthen protection for biotechnological inventions, the European Commission proposed a draft directive related to protection of biotech innovations. The directive was revised and amended several times, aiming to reconcile the contradictory decisions by the EPO regarding the transgenic plants, and to establish more clear-cut definitions for patentability of genetically engineered plants. It was not until July 1998 that the Biotechnology Patent Directive 98/44 was issued. The Directive provides that "inventions which concern plants or animals shall be patentable if the technical feasibility of the invention is not confined to a particular plant or animal variety" (Article 4(2)). Article 11 of the Directive provides somewhat of a farmer's exemption - it permits a farmer to use the harvested material for propagation and multiplication on his own land, but this applies only to certain agricultural plant species listed in Art. 14 Regulation (EC) No. 2100/94.

The ruling of the EPO's Enlarged Board of Appeal in *Novartis AG* (1999) paved the path to patenting transgenic plants. Based on its ruling in the PGS case in 1997, the EPO turned down Novartis' application for a patent on transgenic plants that contained genes conferring pathogen resistance. In December 1999, the EPO's Enlarged Board of Appeals overturned the earlier EPO's decision, stating that the term "plant variety" should be interpreted narrowly, "as a plant grouping delineated by the expression of characteristics that result from a given genotype" (Jones (2000)). The Board ruled that because Novartis' claims to the transgenic plant did not identify characteristics related to homogeneity and stability of the variety, the claimed transgenic plant did not constitute a plant variety. Thus, even though the European Directive 98/44 does not permit the patenting of plant varieties, the term "plant variety" is defined so narrowly that most transgenic plants are now considered patentable subject matter (Perdue (1999)).

2.3.3 The Australian Experience

Throughout most of the twentieth century, plant breeding in Australia was conducted by the public research institutions funded by compulsory growers' levies and government subsidies. Due to public sector involvement in agricultural R&D, achievements in the breeding sector were freely distributed, and up until the mid-1980s there was no protection for plants and animals.

Formation of an Australian plant protection regime began in late 1980s, the new legislation was established, and the existing IP laws were amended in accordance with the international agreements, in particular TRIPS and UPOV. The two most important laws regulating IP in plants are the Patents Act (1990) and the Plant Breeders' Rights Act (1994).

The Patents Act (1990) replaced the previous Patents Act (1952). Under the revised Act, patents can be applied to plant processes and components of a plant variety. The original Plant Breeders' Rights Act, written in accordance with the UPOV-1978, was passed by the federal parliament in 1987. It was amended in 1994 to bring the Australian plant protection law in conformity with UPOV-91. The Act gives the owner the exclusive right to produce or reproduce the protected material, offer the material for sale, and import and export the material. The Act contains a farmer's exemption and a breeder's (experimental) exemption. Saved seed is allowed unless the crop is specifically exempted by regulation. There are, however, currently no crops declared exempt (IP Australia office).

Plant breeding was further encouraged by the passage of the Plant Breeder's Rights Amendment Bill (2002). The main points contained in the bill include:

(1) clarifying the circumstances in which a breeder's right is exhausted;

(2) further protecting commercially sensitive information;

(3) making explicit the right of the owner of a plant breeder's right to initiate infringement actions; and

(4) enhancing the opportunity of the owner of a plant breeder's right to gain a commercial reward (Kingwell (2005)).

Legislative changes in Australia with respect to intellectual property rights for plants have brought about major changes in the agricultural research environment. Applications of biotechnological advances and the possibility of patenting gene sequences have attracted private sector interest driven primarily by revenue-raising opportunities. Research materials and germplasm that used to be placed in the common public pool are no longer freely available, and access to these materials by plant breeders requires becoming a partner or licensing, signing of material transfer agreements, or bag label contracts (Kingwell (2005)).

Introduction of property rights has also changed the structure of research funding in Australian agriculture, with plant breeding activities relying on revenues generated through the marketplace rather than public funds. Kingwell (2005) indicates that end-point royalties and intellectual property payments have been introduced in several Australian States. For example, in 2001/02 the Western Australian Department of Agriculture and Food (DAFWA) had fifteen varieties that were subject to royalty rates that varied from \$0.70/t to \$1.00/t. DAFWA has an agreement with the statutory marketing authorities (AWB and GPWA) and with GrainCo for royalty collection on DAFWA/GRDC varieties grown outside Western Australia. By 2004 DAFWA had 24 varieties subject to royalty rates varying from \$0.45/t to \$4.17/t (Kingwell (2005)).

2.3.4 IP Regime in Canada

The first legislation in Canada to regulate the distribution of seeds was the Seeds Act (1923). Although the primary intention behind the Seeds Act was to prevent seed salesmen from selling bad varieties (Kuyek (2004)), the sections pertaining to the use of a variety name should be considered an early attempt to protect plant varieties. In particular, the Act states that "no person shall sell, import into or export from Canada seed under a grade name or designation so closely resembling an established grade name" or apply the established name to seed or a package containing seed (Seeds Act, 2(a)-(b)). Thus, while the farmers could save the seed for replanting purposes and exchange harvested seed with their neighbours, they could not advertise or sell it using the variety name. Therefore, the Act protected plant breeders from illegal sales of their varieties, and in this sense served as a plant protection tool. At the same time, the Act safeguarded the interests of farmers and breeders. Farmers were allowed to save the seed and breeders were allowed to use it for breeding purposes.

The Seeds Act, however, did not explicitly establish plant breeders' rights over their varieties. It prohibited the sale of seed under a registered variety name in order to ensure a quality seed supply rather than protect plant breeders' IP, the quality assurance regulations offering only indirect protection for breeders. The Seeds Act provided trademark-like protection and did not prohibit the sale of seed as "common grade" or "unclean." The Act was deficient in a few areas, including breeder access to plant breeders' rights protection in foreign countries and few exemptions for farmer and research usage of planting material (Carew (2000)).

The first legal document that explicitly stated the rights of plant breeders concerning developed varieties was the Plant Breeder's Act (1990). Under the Act, the plant breeder has an exclusive right to sell and produce for the purpose of selling a plant variety, and make repeated use of the propagating material of the plant variety to produce another plant variety for commercialization. Canada's Plant Breeder's Act also contains provisions that protect researchers' and farmers' interests: (1) farmers can retain seed from the protected variety without paying royalties to the innovator; (2) the protected variety can be used by researchers in developing other varieties; and (3) the Commissioner of Plant Breeders Rights has the power to issue compulsory licenses if necessary to ensure that a plant variety is made available to the public at reasonable prices, is widely distributed, and its quality is maintained. The main difference between the Plant Breeder's Act and the Seeds Act is that under the former law, the seed of protected varieties cannot be sold even if common grade or "unclean" (Saskatchewan Agriculture and Food (2005)).

Canada's Plant Breeder's Act is based on the 1978 revisions to the UPOV convention. The UPOV convention was further revised in 1991 and signed by Canada in 1992. However, Canada has not yet ratified UPOV-1991 and needs to make amendments to the current PBR legislation to extend coverage to "essentially derived varieties and harvested materials." These amendments were the subject of a bill that died on the Order Paper at the end of the first session of the 36th Parliament in 1999 (Forge (2005)). Thus, in terms of PBRs, Canada lags behind the United States, Australia, and most EU members that adjusted their laws to comply with UPOV-91.

Some argue that IPRs such as PBRs undermine the Canadian breeding programs and assert that advances in plant breeding can continue to be made only through collaborative efforts and open access to existing technologies (Kuyek (2004)). Others, however, argue that PBRs have been an effective tool for fostering the development of new varieties and open access to foreign technologies. A Canadian Food Inspection Agency (CFIA) assessment of the Plant Breeder's Act showed that although the Act offered only a narrow protection, the following benefits have been realized:

(1) stimulation of industry involvement in plant breeding in Canada;

(2) improved access to foreign varieties of plants; and

(3) increased numbers of varieties on the market.

Arguments in support of the Plant Breeder's Act are also presented in Carew (2000, 2005). Following the Plant Breeder's Act's introduction, the private sector's investment into plant breeding in Canada nearly tripled, from \$33.2 million in 1987 to \$92.5 million in 2001 (AAFC (2004)). The pace at which new varieties have been introduced has increased substantially. In the canola sector, for example, in the 1970s and 1980s only one variety was granted rights on

Table 2.5: *Plant protection certificates granted to public and private institutions, 1990-2000*

Commodity	Total	AAFC	Canadian University	Private sector	Country of origin		
					Canada	US	EU
Wheat	17	11	1	3	14	2	1
Barley	20	8	2	3	18	2	-
Oats	5	4	-	1	4	-	1
Canola	83	8	3	72	60	-	23
Soybean	33	4	3	26	25	8	-
Peas	37	3	-	34	4	-	32
Potato	71	2	3	63	8	5	58

Source: Carew (2001)

average every other year, but twenty-four new varieties (all developed by the private sector) were granted rights in 2004 alone (AAFC (2004)). Table 2.5 shows the number of protection certificates granted to the public and private sectors during the period 1990-2000.

A criticism of the CFIA approach to assessing the effectiveness of PBRs in Canada is provided in Kuyek (2004). He states that after introduction of the Act in the soybean sector, for example, only two varieties with PBRs were bred by a private Canadian breeding program. A strong private sector presence in the soybean sector can hardly be the result of the Plant Breeder's Act. The Act also cannot be linked to an increased number of varieties on the market because it might have been the result of recent changes in the merit criteria of the variety registration system. As for the benefits from increased abilities to collect royalties, Brian Rossnagel, a barley breeder at the University of Saskatchewan, indicates that "we collected royalties on varieties way before we had PBRs. In fact, most of the royalties collected at the University of Saskatchewan have been collected on varieties that are not protected. The seed system protects them sufficiently in our opinion" (Kuyek (2004), p. 32). Thus, from a breeders' point of view, the Plant Breeder's Act has not offered more protection than that offered by the Seeds Act.

Another immediate issue is that of patents on IP in agriculture, and plants in particular. A number of policy instruments have been employed in Canada to protect intellectual property. Canada's first Patent Act was passed in 1869, and revised a number of times. These changes include: (1) a first-to-file system; (2) publication of patent applications eighteen months after the date of filing; (3) an exemption for the use of patented inventions for research; and (4) a patent length of twenty years from the date of filing. To facilitate the transfer and diffusion of new technologies, the Patent Act contains a special provision called experimental exemption, which allows use of a patented invention for non-commercial (experimental) purposes (Sec. 55.2). This is in contrast to the United States or Australian IP regimes, where there is no general provision for the use of patented technologies by persons who are not the owners of the invention. In Canada, this experimental use exemption has had limited success, partly because in many cases it is impossible to draw a line between commercial and non-commercial use of the invention (Hope (2003)).

Canadian patent law, however, has never explicitly included plants. For more than a century the federal and provincial governments in Canada were major players in the research industry. Public involvement in research meant that innovations were freely distributed to producers and the issue of developing special legislation to protect intellectual property in agriculture was never raised. Marketplace changes in the 1970s and 1980s, including rapid development of biotechnology industry and significant budget cuts for agricultural R&D, required action from the federal government to attract more private sector investment. Policymakers came to believe that biotechnological advances would allow the introduction of desired traits and development of new cultivars at a faster pace and lower cost compared to what could be achieved via traditional breeding methods. Given the opportunities that biotechnology offered, private industry gained priority in public discussions. At the same time, with the technological breakthroughs that occurred in the biotech industry, it became possible to better identify seeds, which made feasible protection of intellectual property in plant breeding. On the other hand, some innovators suddenly found enormous commercial value in seeds developed through genetic engineering (e.g., the canola industry) and began lobbying for stronger protection of intellectual property in agriculture (Kuyek (2004)).

The legislative response to these developments did not linger, and in 1982 in the *Abitibi Co.* and *Connaught Lab.* cases, the Canadian Intellectual Property office allowed the patenting of single-celled organisms or events within cells, which initiated a new era of protection for plants developed through genetic engineering.

The Patent Act defines a patentable invention as "any new or useful art, process, machine, manufacture or composition of matter, or any new or useful improvement in any art, process, machine or composition of matter." This definition does not explicitly include life forms such as animals and plants. The Canadian Supreme Court's ruling on 5 December 2002 in the Harvard University case (genetically engineered "oncomouse" case) made it clear that the enforcement policy that applies to the Patent Act does not permit patenting of higher life forms, such as animals or plants. This is explained by the fact that higher life forms can reproduce and acquire important characteristics not related to the invention. According to the Canadian Biotechnology Advisory Committee, "if patents rights were simply extended to higher life forms, the patent holder not only would be given rights that inhibit other useful activity, but would also gain rights disproportionate... over other inventions" (Forge (2005)).

At the same time, the IPO's decision in 1982 allowed seed companies to apply patents to the process of splicing genes and inserting them into cells without extending patent protection to living plants, although the end result is still de facto protection of the whole plant. The best example of this is *Monsanto v. Schmeiser.* Application of the patent on its technology allowed Monsanto to sign technology use agreements (TUAs) with farmers that prohibited use of harvested seed for replanting purposes. Schmeiser grew herbicide resistant canola on his property, and the seed he used had not been purchased from a seed company nor had a TUA been signed. Schmeiser realized that he had herbicide resistant canola-he identified the germplasm and harvested and reused the seed. Monsanto's patent involved claims to both a gene and a plant cell. In Canada, however, there are no patent claims to a plant, but Schmeiser used a plant whose gene was patented. This matter made its way through the courts, until the Supreme Court finally ruled that cells and genes are like a legal block, and if something is built out of a legal block or if it gets used, then the legal block is infringed. So, in *Monsanto Canada Inc. v. Schmeiser* (2004), the Supreme Court ruled that Schmeiser infringed upon Monsanto's patent, meaning that a patent related to a plant cell gives the innovator the right to decide what others may do with the plant in question (Forge (2005)). Therefore, protection to transgenic plants allowed by the Canadian Patent Act is similar to protections afforded under the Biotechnology Patent Directive in the EU.

There has been a recent trend to complement PBRs and patents with various contractual arrangements with farmers. For example, C&M Seeds operates an "Identity Preserved Program" in Ontario. Under this program, farmers willing to purchase the seed must sign an "Identity Preserved Growers Agreement" that obliges the use only of certified seed from and delivery of the harvest to C&M Seeds, and prohibits saving the seed for replanting purposes or sharing the seed with other farmers (Kuyek (2004)). In this way, the seed company ensures that a particular wheat variety is not mixed with other varieties, and farmers are paid a premium for delivering the grain produced from this particular variety. This system works very much like IPRs because farmers are induced to purchase the certified seed every growing season if they wish to receive a premium for delivering "quality" grain.

In summary, plant breeders in Canada currently operate under two forms of IP protection, patents and PBRs. Patents can only be applicable to transgenic plants where the within-cell processes, rather than entire plants, are patented. Conventionally bred crops, on the other hand, can only be protected by PBRs. Protection offered by PBRs is similar to that envisioned by the Seeds Act (1923) in the sense that both allow farmers to save the seed for subsequent reproduction. In contrast to the Seeds Act's regulation, which allows the sale of seed under the "common grade" name, PBRs protect the seed developers from others' commercial activities involving their seeds.

2.4 Concluding Comments

Protection of intellectual property is an important component of the innovation incentive system. Because research requires enormous investment, both in money and time, and because intellectual property (knowledge) possesses public good features, such as non-excludability and non-rivalry, a special mechanism is required to allow developers to recoup R&D expenditures. To provide such a mechanism, many countries have developed intellectual property rights laws that provide protection in the form of patents, trademarks, or trade secrets.

Despite the existence of laws protecting intellectual property, plant breeding rights have always been treated differently. First, protection of plants is hard to justify because they embody indigenous knowledge that has been in the public domain for generations. Second, intellectual property in plants is hard to enforce due to the ability of plants to reproduce and the inability of a seed developer to distinguish his seed if it were developed through traditional methods. For these reasons, special mechanisms were designed to protect plants.

Even before the establishment of plant protection systems in many countries seed sales were regulated by seed laws. These laws, however, provided only a weak protection because they did not prohibit farmers from growing their own seed and exchanging it with others. Some countries strengthened plant IP protection by introducing plant breeders' rights.

Advances in biological science in the 1970s and 1980s allowed breeders to identify their plants, which favoured establishment of a stronger plant IP protection regime. A new era in the protection of plants started with a seminal decision of the United States Supreme Court in 1980 (*Diamond v. Chakrabarty*), which allowed the patenting of life forms, including plants. This position was followed, a decade later, by Japan and Europe.

As plant IPRs were evolving, the national character of protection laws necessitated the development of a system that would harmonize plant IPRs laws internationally. This issue was first addressed in the 1960s, when a number of European countries signed the UPOV convention, which obliged member countries to provide protection for plants in the form of Plant Breeders' Rights. As of October 2007, sixty-five countries have become members of the UPOV convention (UPOV (2007)).

As a trade-related issue, plant protection was addressed in the TRIPS agreement (1994). It obliged member countries to provide either patents or a *sui generis* system for plants. Developed countries are currently promoting IPRs in developing countries by signing bilateral agreements (TRIPS-plus) intended to bring plant IP protection in conformity with the "highest international standards."

Despite the efforts to harmonize IP laws, protection still varies from country to country. All the industrialized countries, with the exception of six EU member countries and Canada, are complying with UPOV-91. Patents for plants are available in the United States, Japan, and Australia. The EU and Canada grant patents for *transgenic* plants by allowing protection for genetically modified cells and the process for transferring genetic material.

Because innovation is crucial for economic growth and a country's competitive advantage, there are concerns that the gap in plant protection available in Canada and other industrialized countries might hinder Canada's scientific research. Some argue that in order to catch up with the technological leaders, Canada must adjust its plant IPRs laws to close this gap. Canada is already proceeding toward a patent system for biotechnology applications, and may follow the United States by allowing patents for all kinds of plants. Before plant IP protection changes occur, it is important to have a clear understanding of the effects of different IPR regimes on R&D incentive structure, farm/consumer welfare, and abilities to conduct cumulative research. These impacts of strengthened IPRs are explored in the remainder of the thesis. Chapter 3 compares patents to PBRs in terms of their impact on farmers and incentives to innovate. Chapter 4 develops a game theoretic model to explain the incentives of firms to share upstream innovations in the world of IP protection. Chapter 5 qualifies the impact of IPRs on the ability of plant breeders in Canada to access research inputs and conduct research.

Chapter 3

INCENTIVES TO INNOVATE AND RESEARCH BENEFITS FROM AGRICULTURAL R&D UNDER IP PROTECTION

3.1 Introduction

Plant breeders in Canada currently operate under two forms of intellectual property rights: UPOV-78 compatible Plant Breeders' Rights (PBRs) and patents. PBRs can be applied to any crop variety that is distinguishable from existing varieties, while patents can be applied to the process of inserting genes, and are therefore available only for genetically engineered plants. In recent years, these two forms of protection have been complemented by contractual arrangements with farmers intended to strengthen IPR enforcement.

PBRs are similar to patents in that they provide the owner with exclusive commercial rights for a limited period of time, but at the same time some attributes of patents are missing in PBRs. A notable difference between PBRs and patents is the "farmer's exemption" or "privilege" that allows farmers to keep part of the harvest for replanting in subsequent years. Therefore, the PBR owner effectively has monopoly over the plant for only the initial sale of the plant or seed, while a patent owner has exclusive rights to exploitation of the plant or seed for the life of the patent (Advisory Council on Intellectual Property (2002)). Because of this exemption, PBRs are considered a weaker form of plant intellectual property protection.

Innovations in the seed sector are fundamentally different from inventions in other sectors. A unique feature of seeds of self-pollinating plants is their ability to produce second-generation seed. If sown, these seeds will produce plants identical to the first-generation, and part of the harvest can be used as seed for further reproduction. Therefore, due to self-reproducibility, seed has a durable aspect to it in that once purchased it can be replanted from year to year, thus yielding a flow of benefits to the farmer over a significant period of time. Farmer's exemption under PBRs renders seed a legal durable (Perrin and Fulginiti (2004)). Unlike other durable goods, however, the seed needs to be reproduced at a cost in order to yield benefits in subsequent periods.

A number of studies suggested that when a product is durable, the monopoly rents gained from selling the product are dissipated (Coase (1972), Bulow (1986), Perrin and Fulginity (2004)). The basic intuition behind this premise is that product durability implies that future output will have to compete with today's purchases, thus forcing the monopoly seller to reduce the price over time. Anticipating this behaviour, buyers will want to wait for the next period's lower price, which will drive down current demand and price.

The farmers' exemption envisioned by current PBR legislation has been associated with an erosion of seed industry sales and, therefore, has been considered one of the barriers to seed industry innovation (Shand (1994), Canadian Trade Seed Association (2008)). The International Seed Federation claimed in 2005 that in eighteen countries surveyed, farmer-saved seed represented an average loss to the seed trade of almost $7 billion annually (GRAIN (2007)). As a result of extensive (and legally permitted) seed saving practices, the effectiveness of PBRs in promoting the development of improved varieties have been questioned in a number of empirical studies (Alston and Venner (2002), Perrin, Hunnings, and Ihnen (1983), Carew and Devadoss (2003)).

However, it can also be argued that the possibility of reproducing the material and future value that it creates can be reflected in increased willingness to pay for that material, thus allowing the seller to indirectly appropriate the rents from reproduction by charging a high price on the original (Liebowitz (1985), Besen and Kirby (1985), Hansen and Knudson (1996)). As a matter of fact, when the introduction of PBRs was first discussed, there was apprehension of farmer groups over a loss of seed control and increased cost of seed if private industry came to dominate the field (CBC (1987)). This reflects the idea that PBRs can allow the seed developer to indirectly appropriate the economic value of a new crop variety by charging a high price on the parent seed and be effective in attracting private sector investment, thereby fostering varietal development.

Thus, an interesting economic issue is: What is the ability of a seed developer to capture the economic value of PBR-protected technology upfront versus every period when the technology is protected by patents? The answer to this question could help to locate PBRs and patents in terms of their abilities to promote innovations in the seed industry.

The effectiveness of IPRs in promoting the development of improved varieties is not, however, the only issue about which policy makers should be concerned when designing a plant intellectual property protection policy. An important question is whether the research incentive created by the patent monopoly is substantial enough to outweigh the costs of that patent monopoly. Some argue that even though patents may better serve to encourage innovation, they are not entirely appropriate in that they do not strike the proper balance between farmers' interests and the exclusive ownership rights of plant breeders to exploit their new plants and plant genes (Derzko (1994)). Those opposed to patents argue that farmers will be worse off if saved seed is eliminated, as benefits from the new technology will not justify the cost increase. Proponents of stronger IPRs argue that elimination of farmer-saved seed can offer significant varietal improvements, such that benefits from new seed outweigh the costs, thus leading to increased welfare in both the farm sector and the seed industry. Thus, an interesting economic question is whether patenting can ensure development of superior varieties such that farmers are better off than under PBRs.

The purpose of this dissertation is to compare the effectiveness of PBRs and patents as a stimulus for encouraging innovation and gain insight into the distributional aspects of PBRs versus patents. To achieve this, a three-stage model is set up to analyze the developments in the seed and farmer sectors. In the first stage, the seed developer decides on the R&D effort that determines the improvement of the new variety over the generic one. The second stage encompasses the initial period after the release of the new variety. In the second stage, heterogeneous farmers make adoption decisions and the seed company forms the pricing strategy, depending on the nature of intellectual property rights. The third stage covers the second period after the release of the variety, and consists of second period pricing and adoption decisions. Solving for the equilibrium strategy at every stage yields an adoption pattern, the pricing and R&D strategies that are used to compare the outcomes under PBRs and patents.

This chapter is structured as follows. Section 3.2 discusses the literature on the distributional effects of IPRs, product durability, copying, and appropriation of rents. In section

3.3, a theoretical model is provided to analyze the R&D incentive structure and the structure of benefits from research under PBRs. Section 3.4 extends the analysis to patents. Welfare implications of the two forms of protection are provided in section 3.5. Section 3.6 concludes the analysis.

3.2 Related Literature

3.2.1 The Distributional Effects of IPRs

Changes in technology in the 1980s and 1990s spurred private investment in the crop research industry. Increased interest from private sector has been accompanied by a strengthening of IPRs. The welfare of IPRs and farmers dominate current debates. Opponents of IPRs argue that exclusive rights over the seed give the developer the power to charge high seed prices such that farmers do not gain from agricultural innovations. The proponents of stronger IPRs argue that technological improvements brought about by more R&D more than offset the cost increase, thus benefiting farmers.

The theoretical model developed in this study examines the distributional effects of patents versus PBRs in the seed industry. It is therefore related to the literature that attempts to gain insight into the impact of IPRs and privatization of agricultural research on the distribution of benefits among different economic agents - innovators, farmers, and consumers.

A paper by Moschini and Lapan (1997) was one of the first attempts to set up a theoretical framework for analyzing the welfare effects of agricultural R&D in the presence of IPRs. In their model, the innovated input is introduced into the competitive agricultural market. The innovator acquires a patent for the invention, which gives him the power to exercise above marginal cost pricing. The bottom line in the analysis is that under IPRs the price of improved inputs increases, which affects the use of a new technology and the actual benefits realized. The authors distinguish between a case where the innovation is "drastic" (the innovating firm can charge the monopoly price) and "non-drastic" (the firm is constrained to charge the upper bound). They show that when the input of interest is initially competitively priced and the innovation is non-drastic, then the post- and pre-innovation supply curves coincide and the farmers' and consumers' surpluses are unchanged, which contradicts the general idea of

R&D being beneficial for producers and consumers. With a preexisting monopoly, non-drastic innovation, and two firms engaging in Bertrand competition, some portion of the generated surplus goes to farmers and consumers. In a case of drastic innovation, the efficiency price of a new input declines, which leads to a larger output and lower price in the agricultural market. As a result, consumers unambiguously gain, but whether the farmers gain or lose depends on demand elasticity.

Moschini, Lapan and Sobolevsky (2000) extend the analysis suggested by Moschini and Lapan (1997) to an open economy and apply the model to the soybean sector. They evaluate the welfare effects arising from the adoption of Roundup Ready (RR) soybeans. The results show that, depending on the adoption scenario, the innovator captures the largest portion of the benefit (44-75%), with 10-16% and 15-40% of the surplus going to farmers and consumers, respectively.

Falck-Zepeda et al (2000) have conducted similar research. They measure the benefits from the introduction of Bt cotton to U.S. farmers, the gene developer (Monsanto) and the germplasm supplier (D&PL) and consumers. The authors find that of the total surplus, the largest share (59%) went to American farmers, while 21% and 5% of the surplus was transferred to the gene developer (Monsanto) and the germplasm supplier (D&PL), respectively. The gains to American consumers amounted to 9% of the total surplus.

Falck-Zepeda et al (2000) also apply the analysis to the Herbicide-Tolerant (HT) soybeans. In contrast to Moschini, Lapan, and Sobolevsky's (2000) findings, where a major portion of the surplus goes to the innovators, Falck-Zepeda et al find that American farmers and consumers capture 76% (29% for the American supply elasticity of 0.92) and 4% (17%) of the surplus, respectively. The innovators share amounts to 10% (25%).

3.2.2 Product Durability, Copying and Appropriation of Benefits

Literature on IPRs in agriculture has, for the most part, focused on the distributional aspects of plant protection and innovation efforts without discriminating between different types of protection, such as PBRs and patents. A number of recent studies have endeavoured to extend the analysis to look at how PBRs and patents are different in terms of rewards to the innovator. Moschini and Yerokhin (2007), for example, examine how "research exemption" clause of PBRs makes them essentially different from patents in terms of incentives for private firms to innovate. The model developed in the following sections is valuable as it complements the Moschini and Yerokhin's (2007) work by looking at the other important aspect of PBRs called "farmer's exemption". To the best of the author's knowledge, no study has looked at the impact of "the farmer's exemption" and seed *durability* on the ability of the innovator to appropriate the rents from research, incentive to innovate, and farmers' welfare.

Literature on the pricing of durable goods traces back to Coase (1972). In his model, the monopolist offers a durable product for sale. In the first period, the monopolist sets the monopoly price and only a fraction of customers purchase the good. In the second period, the monopolist can attract some of the remaining customers by lowering the price. In each period the monopolist will face a residual demand and have a strong incentive to lower the price until the price falls down to marginal costs. Coase argues that the rational buyer will anticipate a price reduction over time and wait for the next period's lower price. He concludes that, given buyers' rational expectations, with "complete durability the price becomes independent of the number of suppliers and is thus always equal to the competitive price" (Coase (1972), p. 144). Therefore, without credible commitment that the price will not be reduced, the ability of the durable good seller to price discriminate is undermined and the seller earns no rents. This conclusion has been termed "Coase's conjecture."

Rent dissipation in a case of a durable good occurs because consumers are patient, transactions take place quickly and with no barriers, and the monopolist cannot commit about future production. When capacity is limited or when the monopolist can credibly commit about future production, the monopolist's problem is mitigated. The problem will also persist in a less severe form as long as consumers of durable goods incorporate into their decisions the tendency of future prices to decline, even if the Coase's assumptions about costless and quick transactions and no precommitments are dropped (Butz (1990)).

A certain amount of precommitment is embodied in discrete time models where production occurs at the beginning of a period and nothing is produced until one period later (Bulow (1982)). Bulow (1982) develops a two-period model where the outcomes from *renting* and *selling* a durable good are compared.[1] The author shows that the surplus of the durable-

[1]There is an analogy between selling a PBR-protected seed and selling a durable good, and between selling

goods monopolist will not be fully dissipated, as Coase's conjecture suggests. This occurs due to a discrete time framework that serves as a precommitment device. He concludes that renting a durable good will yield unambiguously higher profits than selling.

Bulow (1982) assumes that there are no costs associated with renting. The optimal strategy for the monopolist will be to undertake production only in the first period and rent the produced units in the second. No production costs, then, are incurred in the second period. Even though a line can be drawn between renting durable goods and selling patented seed, the problem here is different. Selling patented seed requires that a seed company produce seed every period, thereby incurring seed production costs every year. Selling the seed and letting farmers produce their own seed would allow the company to save on seed production costs. Therefore, there is a trade-off between selling every period and paying seed production costs, and selling once, as under PBRs, and avoiding these costs, something that is not captured in Bulow (1982).

Perrin and Fulginity (2004) have applied the durable goods theory to the seed sector. Given heterogeneous users' valuations, the authors examine the monopolist's pricing of a non-durable crop trait (hybrid or patent protected variety) and a durable crop trait (PBR-protected variety). The authors conclude that when farmers are legally allowed to replant the seed and PBRs are perfectly enforced, then the initial price that the seed developer is able to charge is only a quarter or so of the one-shot monopoly price, with the seller's returns going below even this level when piracy occurs.

Results derived by Perrin and Fulgninity (2004) have important implications for innovation in the seed industry. The inability of seed developers to appropriate rents under PBRs can lead to a lack of incentive to perform varietal development. The authors, however, do not extend the analysis to study the R&D incentive structure, nor do they look into welfare implications of patents versus PBRs.

The above studies have shown that product durability reduces a seller's returns because later output will have to compete with today's purchases. Thus, in light of the theoretical literature on durable goods, the farmer's exemption under PBRs can be viewed as a drain on

a patent-protected seed and renting a durable good. Therefore, this study is of importance because it explains the main forces at work.

demand and revenues, and, consequently, as a weak instrument to enhance innovation. This has also been supported by a number of empirical studies discussed below.

Alston and Venner (2002) test the effect of the American Plant Variety Protection Act (PVPA) on varietal improvement in wheat. To achieve this, the authors link the passage of the PVPA in 1970 to private involvement in wheat breeding, seed price or royalty rate, and commercial and experimental yields. In general, no evidence of increased private investment, increased price or royalties, and increased wheat yields is found. Therefore, the authors conclude that the adoption of PVPA did not lead to an increase in excludability or appropriability of returns to investments, and, therefore, had no discernible effect on the rate of genetic improvement.

Carew and Devadoss (2003) econometrically test the relationship between canola yields in Manitoba and the enactment of PBR legislation in 1991. They find no evidence that PBRs encouraged development of higher-yielding varieties.

While the above studies support the idea that a farmer's exemption erodes the profits of the seed developer and therefore leads to a lack of incentive to innovate, a separate stream of literature has emphasized the possibility of *indirect* appropriation of benefits from the materials that can easily be reproduced (Liebowitz (1985), Besen and Kirby (1989), Johnson (1985)). In this literature, the demand for the original material reflects the value to be gained from reproduction and, therefore, allows the seller of the original to partially appropriate the future stream of benefits by charging a high enough price when selling the original.

The relationship between copying and the ability to appropriate rents is relevant to the present problem because seed, unlike other durable goods, multiplies and requires a farmer to incur reproduction costs every period, just as copiers have to pay the cost of copying. Besen (1986) shows that copying increases producer profits if the marginal cost of a copy is less than the marginal cost of an original and if the price captures the value of the copies made from each original. This occurs because the seller is able to substitute efficient reproduction of the originals for his own production. Besen and Kirby (1989) demonstrate that, with rising marginal costs of copying, in certain cases the possibility of copying (reproduction) can make producers of originals better off.

In agriculture, the test of indirect appropriation of rents was empirically performed for the soybean sector by Hansen and Knudson (1996). The authors find that seed firms have been able to appropriate indirectly the value of genetic material up front. Therefore, they conclude, a farm seed saving practice can exist without decreasing incentives for varietal development.

While the literature on indirect appropriability suggests that a seed developer can capture the rents by charging a high enough price on the parental seed, it does not incorporate dynamic price effects of intertemporal competition allowed for in Coase. The present work looks into the ability of a seed company to capture the value up front, given that future pricing policy is incorporated in today's purchase decisions.

3.3 Theoretical Framework: Research Incentives and the Distribution of Benefits from Research Under PBRs

A three-stage model of a durable-good market is employed in this study. In Stage 0, the seed company decides how much R&D to undertake to generate a new variety. Stage 1 covers the first period after the new variety is introduced to farmers' fields. In this stage, the seed company forms its pricing strategy and farmers make adoption decisions. Stage 2 covers the second period, after the introduction of the new variety, and encompasses, like Stage 1, adoption and pricing decisions.

Model Set-Up

It is assumed that there is a continuum of farmers who are differentiated according to some characteristic a that lies in [0;1] range. It is also assumed that each farmer has h acres and employs either new or the existing public technology, and that returns to the existing variety are the same across farmers. Farmers are assumed to be distributed uniformly, and each farmer uses one unit of input (seed) to produce output.

In Stage 1 of the game, the farmers decide whether to plant the existing public variety offered on the market at price w^e per acre or to buy the new variety from the monopolistic research firm at price w_1^n. (Throughout the text, a superscript e will be used to denote the existing variety; n - the new variety; and o - own produced seed.) When farmers make their decisions perfect anticipation is assumed - farmers perfectly anticipate the outcomes at all stages of the game such as future yield and the future pricing strategy of the seed company.

The yield of the existing variety is y^e. The new variety developed by the monopolistic life-science company yields $y^e + i_1$, where i_1 is a per acre benefit to the adopting farmers in Stage 1 of the game. This benefit can come from increased productivity of the new variety, improved quality, reduced costs, or a combination of the above. Benefits from the new technology are not equally valuable for all farmers, but rather depend on soil characteristics, farm pest problems, and the farmer's management skills, among other variables. Thus, only a portion of farmers will adopt the new technology once it becomes available (early adopters). Those farmers who purchase the seed in Stage 1 retain the harvested seed and use it for subsequent production in Stage 2, which is a special provision of the Plant Breeders' Rights Act, but they cannot sell the saved seed to neighboring farmers. Perfect enforcement of PBRs is assumed.

Some farmers adopt the new technology only in Stage 2 (late adopters), while others keep seeding the existing generic variety throughout the game (non-adopters).

When the variety is released, farmers are not fully aware of how to use the technology, which prevents them from reaching the potential benefit. Over time, however, farmers learn how to use the new technology. The learning curve is demonstrated by the fact that for each farmer the benefit from the new technology in Stage 2, i_2, increases with the total area seeded with the new variety in Stage 1. That is,

$$i_2 = i_1 + kx_1,$$

where x_1 is the total area seeded with the new technology in Stage 1 and k is the parameter that captures the degree of learning in agriculture. It is assumed that, over the years, farmers observe what the adopters do and, thus, learn how to better use the technology. The more area is planted with the new technology the more experience farmers gain, and the greater the benefits of the new technology.

The derived demand for seed in each stage of the game is found by comparing a farmer's profit from the adoption alternatives. Given the derived demand in Stage 1 and Stage 2, the seed company will decide how much seed to produce and what price to charge at each stage.

The seed sector in Canada is currently highly concentrated, and in this study it is modeled as monopolistic. Until 1980s, the development of new varieties and agricultural R&D were mostly the responsibilities of the public sector. The invention of gene engineering that allowed life science companies to reduce developmental costs and strengthen intellectual property rights increased private sector agricultural research expenditures. The shift in breeding research programs from the public to private sector in Canada occurred in the 1980's, when the federal government faced budget constraints and, partly to replace diminishing public funds, large agrochemical companies jumped into the plant genetic industry. Currently, the seed industry is represented by six big players in agriculture-BASF, Bayer, Dow AgroSciences (Mycogen), DuPont (Pioneer), Monsanto (DeKalb, Asgrow), and Syngenta (Northrup King). It is believed that consolidation will continue and that this number will be reduced to three or four major players in the coming years (Lawton (2003)). Therefore, the assumption of a monopolistic seed industry is not unrealistic.

The work proceeds by characterizing the subgame-perfect equilibrium in this game. The time-consistent solution to this three-stage game model, one in which neither the research firm nor farmers have incentives to revise production or pricing decisions, is obtained by solving the game by backward induction. Starting from the farm sector in Stage 2 one can derive the demand for seed. Given the derived demand, the seed company's pricing strategy is solved in Stage 2, which permits returning to the optimization problem in Stage 1. R&D effort is determined at the final stage.

3.3.1 Stage 2: Adoption and Pricing Decisions

Farm Sector

The options available to the farmers in Stage 2 are constrained by the decision made in Stage 1. It is assumed that once farmers have planted the new technology in Stage 1 they will have no incentive to switch back to the old technology. Thus, this group of farmers cannot reverse their decision made in Stage 1 once they get to Stage 2 and their choice in Stage 2, therefore, is predetermined by their decision in Stage 1.

Taking this into consideration, in Stage 2 only the first period non-adopters have the freedom to make a choice. Two options are available for farmers who employed the traditional (generic) technology in Stage 1: (1) they can either try the new technology in Stage 2; or

(2) they can continue using the existing public variety. The possibility of brown-bagging is excluded in this model. Therefore, those farmers who decide to switch to the new technology in Stage 2 must buy the seed from the seed company at a price w_2^n. The per acre profit in the second period for this group of farmers is:

$$\pi_2^n = p_2^f y^e + i_2 - w_2^n - c^f - \lambda a,$$

where π_2^n is the per acre profit from adopting the new technology in Stage 2, p_2^f is the price the farmer receives for a unit of output and is the same irrespective of which variety is used for planting, c^f is the per acre production cost excluding seed cost, and λ is a profit reduction factor. The parameter λ captures the additional costs to the farmer associated with adoption of the new variety.

This work considers the scenario where innovation takes place in a small open economy. The implication of this is that the world market exogenously determines the price that farmers receive. Therefore, this model does not capture the effect of increased/reduced supply on the farmer's price.

If the existing generic variety is planted, the per acre benefit is given by:

$$\pi_2^e = p_2^f y^e - w^e - c^f,$$

where π_2^e is a per acre profit from adopting the existing technology in Stage 2.

When making the decision whether to adopt, a farmer with a differentiating characteristic a compares the profit from adoption, π_2^n, and non-adoption, π_2^e. The marginal type is found by equating π_2^n and π_2^e, and is characterized by the following equation:

$$a^{en} = \frac{i_1 + kx_1 - w_2^n + w^e}{\lambda}, \tag{3.1}$$

where the substitution $i_2 = i_1 + kx_1$ is made.

When farmers are uniformly distributed with a differentiating characteristic a, the above equation shows the number of farmers who will be willing to plant the new technology in Stage 2 of the game. Therefore, the level of a corresponding to the indifferent farmer, a^{en}, determines the market share of the new technology in Stage 2. The market share of the existing public technology is given by $1 - a^{en}$. Since the mass of farmers is normalized at unity, the market share a^{en} gives the total demand for seed. However, the demand that the seed company faces in that stage is only a portion of (3.1) because early adopters have their own seed. Therefore, the demand for the seed from the seed developer in Stage 2 is $a^{en} - x_1$:

$$x_2 = a^{en} - x_1 = \frac{i_1 - w_2^n + w^e + (k - \lambda)x_1}{\lambda}. \tag{3.2}$$

The total area planted with the new technology in the first period has two effects on the seed demand in the second period. On the one hand, because farmers can retain their own seed, more purchases in the first period imply less purchases in the second, which is represented by a negative λx_1 in the demand equation. On the other hand, higher adoption rates in the first period allow for more learning, and the second period demand is increased due to farmers' becoming more familiar with the new technology. The effect of learning is captured by the positive kx_1 term in the demand equation. Because generally one would expect first period seed sales to reduce second period seed demand, it is assumed that $k < \lambda$.

The choice of farmers in Stage 2 is depicted in Figure 3.1. For non-adopters in Stage 1, a switch to the new variety in Stage 2 makes sense when the return from buying the new technology is at least as great as the return from using the traditional seed. This binds for the marginal type, a^{en}, which is indifferent between planting the new seed in Stage 2 and adhering to the traditional technology. a^{en} gives the total area under the new technology in Stage 2, of which x_1 is planted by early adopters with the harvested seed and is, therefore, not part of the seed demand in Stage 2 of the game.

Seed Company

The firm makes its profit-maximizing decisions by selecting the amount of R&D for the new seed and by selecting the optimal price and quantity in each stage. It is assumed that the firm's marginal costs of producing seed are c and are less than the price of the generic variety.

Using equation 3.2, the research firm solves the following profit maximization problem in Stage 2:

$$\max_{x_2} \Pi_2 = x_2(w_2^n(x_2) - c) = (i_1 + w^e + (k - \lambda)x_1 - \lambda x_2 - c)x_2.$$

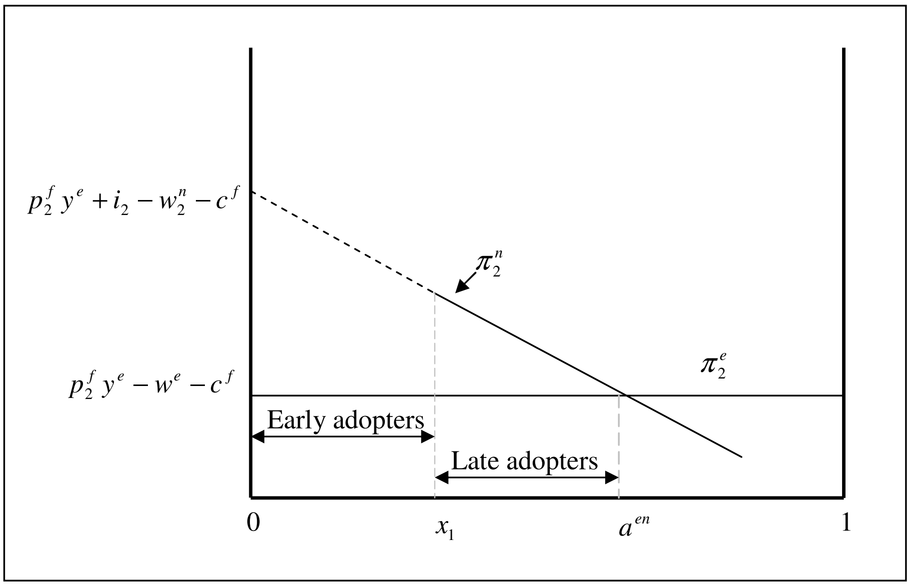


Figure 3.1: Stage 2 - Farmers planting decisions

Differentiating the profit function with respect to x_2 yields the following first order condition:

$\frac{\partial \Pi_2}{\partial x_2} = i_1 + w^e + (k - \lambda)x_1 - c - 2\lambda x_2 = 0.$

Optimal production of the seed of the new variety in Stage 2 and the price are:

$$x_2^* = \frac{i_1 + w^e + (k - \lambda)x_1 - c}{2\lambda}, \tag{3.3}$$

and

$$w_2^{n*} = \frac{i_1 + w^e + (k - \lambda)x_1 + c}{2}. \tag{3.4}$$

Under this pricing strategy the research firm earns the second period profit

$$\Pi_2^* = \frac{(i_1 + w^e + (k - \lambda)x_1 - c)^2}{4\lambda}. \tag{3.5}$$

3.3.2 Stage 1: Adoption and Pricing Decisions

Farm sector

In Stage 1 following the release of a new variety the per acre profit of a farmer with a differentiating characteristic a is:

$\pi_1^e = p_1^f y^e - w^e - c^f$ if the existing public variety is sown, and

$\pi_1^n = p_1^f y^e - (p_1^f \phi + c^c) + i_1 - w_1^n - c^f - \lambda a$ if the new variety is planted,

where ϕ is a per acre seeding rate and c^c is the cost of cleaning the seed incurred when the farmer's own seed is used.

At the end of Stage 1, early adopters retain part of the harvest for re-planting purposes. The price of the retained seed or farmer's reproduction cost, ($c^r = p_1^f \phi + c^c$), enters the profit in Stage 1 and consists of the foregone revenue, $p_1^f \phi$, plus the cleaning cost, c^c.

When making decisions in stage one farmers compare the net present value of the alternatives. The net present value of profits for the three categories of farmers is:

(1) When the existing public variety is planted in both periods (non-adopters)

$$\pi^{ee} = p_1^f y^e - w^e - c^f + \delta p_2^f y^e - \delta w^e - \delta c^f, \tag{3.6}$$

where δ is a discount factor that lies in the [0;1] range.

(2) When the existing variety is used in the first period and the new variety in the second (late adopters)

$$\pi^{en} = p_1^f y^e - w^e - c^f + \delta p_2^f y^e + \delta i_1 + \delta k x_1 - \delta w_2^n - \delta c^f - \delta \lambda a. \tag{3.7}$$

(3) When the new technology is adopted in Stage 1 and self-produced seed in Stage 2 (early adopters)

$$\pi^{no} = p_1^f y^e - c^r + i_1 - w_1^n - c^f - \lambda a + \delta p_2^f y^e + \delta i_1 + \delta k x_1 - \delta c^f - \delta \lambda a. \tag{3.8}$$

The farmer's choice is depicted in Figure 3.2. Farmers choose the technology that yields the highest net present value of per acre profit. A farmer with a differentiating characteristic a equal to zero earns the highest profit from planting the new variety in both stages. Moving to the right along the a axis, the profit from using the new technology in both stages declines. For farmers who buy the new technology in Stage 1, the discounted return from Stage 1 and Stage 2 should be at least as great as the discounted return from planting the traditional variety in Stage 1 and waiting until the next stage to purchase the new variety. The farmer with a differentiating characteristic a^{no} is just indifferent between purchasing the new variety in stage 1 with a subsequent use of the retained seed in Stage 2 and waiting until the next stage to purchase the new technology. If total land acreage is normalized to 1, then a^{no} represents the share of land planted with the new variety and $1 - a^{no}$ is the share of land devoted to the generic variety in Stage 1. Given the assumption that the output price is

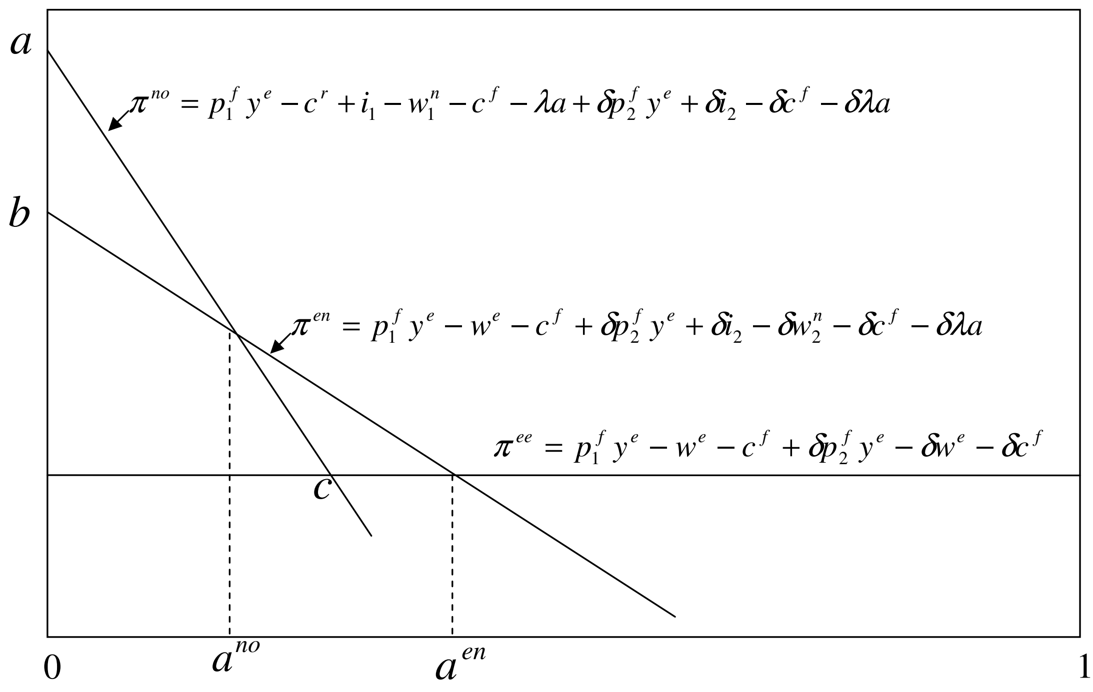


Figure 3.2: Stage 1: Adoption decisions under PBRs

exogenously determined by the world market, a^{no} is the demand for the seed of the new variety in Stage 1.

Following the discussion above, in Stage 1 the demand for the innovated seed that the life-science company faces is:

$$x_1 = a^{no} = \frac{i_1 + w^e + \delta w_2^n - c^r - w_1^n}{\lambda}. \tag{3.9}$$

As can be seen, this is a downward sloping demand curve, with the slope being a function of the parameter λ. Note that in Stage 1, when planting decisions are made, farmers take into consideration the future pricing policy of the seed company. If they expect a price reduction in Stage 2, w_2^n, some farmers will choose to wait until the next stage, which will reduce sales in Stage 1. This is consistent with the Coase's conjecture - buyers' anticipation of lower future prices erodes today's sales.

As can be seen from Figure 3.2, for seed demand in Stage 1 to be positive π^{no} must intersect the vertical axis above point b. This condition reduces to

$$w_1^n - \delta w_2^n < w^e - c^r + i_1. \tag{3.10}$$

The higher the seed price in Stage 1 the lower the chances that the above condition will hold, and that, therefore, the lower the chances that farmers will be willing to purchase the seed in Stage 1. Whether farmers are willing to adopt the new technology in Stage 1 also depends on their reproduction costs. If reproduction costs are zero, then the right-hand side of (3.10) is positive, and the first period price can be higher than the second period price. An increase in reproduction costs makes the right-hand side of (3.10) smaller, thus implying a reduction in the first period seed price.

For the seed demand in Stage 2 to be positive, π^{en} must intersect π^{ee} to the right of point c. This can be reduced to the following condition:

$$w_1^n - (\frac{\lambda}{\lambda - k} + \delta)w_2^k > (i + w^e - c^r) \tag{3.11}$$

As can be seen from the above equation, the higher the first period price the more likely it is that (3.11) holds. Therefore, a higher seed price in Stage 1 encourages more demand in Stage 2. If there are no reproduction costs, then for the second period demand to be positive the left-hand side of (3.11) also has to be positive, implying that *the second period price must be lower than the first period one* . If not, no farmers will choose to adopt the new technology in Stage 2.

The Seed Company Problem

It is assumed that farmers know about seed company incentives and, therefore, the anticipated Stage 2 price is given by (3.4). Substituting this into equation 3.9 yields the indirect seed demand function in Stage 1:

$$w_1^n = \frac{(2+\delta)(w^e + i_1) - 2c^r - (2\lambda - \delta k + \delta\lambda)x_1 + \delta c}{2}. \tag{3.12}$$

The sub-game perfect Nash equilibrium in Stage 1 is found by maximizing the present value of the expected profit:

$$\max_{x_1} \Pi = \Pi_1 + \delta\Pi_2^* = x_1(w_1^n(x_1) - c) + \frac{\delta(i_1 + w^e + (k-\lambda)x_1 - c)^2}{4\lambda}.$$

The FOC for this problem is:

$\frac{\partial \Pi}{\partial x_1} = 0 = (2\lambda + k\delta)(i_1 + w^e) - 2\lambda c^r - (2\lambda + \delta k - 2\lambda\delta)c - (4\lambda^2 + \lambda^2\delta - \delta k^2)x_1.$

The second order condition to ensure the concavity of the profit function in x_1 is that

$$4\lambda^2 + \lambda^2\delta - \delta k^2 > 0. \tag{3.13}$$

This yields the following seed quantity in Stage 1:

$$x_1^* = \frac{(2\lambda + k\delta)(i_1 + w^e) - 2\lambda c^r - (2\lambda + \delta k - 2\lambda\delta)c}{4\lambda^2 + \delta\lambda^2 - \delta k^2}. \tag{3.14}$$

Substituting this expression in (3.3), (3.4) and (3.12) generates the optimal pricing and production decisions as functions of the innovation effort i_1.

The seed price in Stage 1 is:

$$w_1^{n*} = \frac{(\delta^2\lambda^2 + 4\delta\lambda^2 + 4\lambda^2 - k\lambda\delta^2 - 2k^2\delta)(i_1 + w^e) - (4\lambda^2 + 2k\lambda\delta - 2k^2\delta)c^r + Bc}{2(4\lambda^2 + \lambda^2\delta - k^2\delta)}, \tag{3.15}$$

where $B = 4\lambda^2 + 2\delta\lambda^2 + 3k\delta^2\lambda - \delta^2\lambda^2 - 2\delta^2k^2$.

The Stage 2 price is given by:

$$w_2^{n*} = \frac{(\delta\lambda^2 + 2\lambda^2 - k\delta\lambda + 2k\lambda)(i_1 + w^e) + (6\lambda^2 + 3k\delta\lambda - \delta\lambda^2 - 2k\lambda - 2k^2\delta)c - 2\lambda(k - \lambda)c^r}{2(4\lambda^2 + \lambda^2\delta - \delta k^2)}. \tag{3.16}$$

The supply of seed in Stage 2 is:

$$x_2^* = \frac{(\delta\lambda + 2\lambda + 2k - k\delta)(i_1 + w^e) - 2(k - \lambda)c^r - (2\lambda + 3\delta\lambda + 2k - 3k\delta)c}{2(4\lambda^2 + \lambda^2\delta - \delta k^2)}. \tag{3.17}$$

For $\lambda > k$ it can be unambiguously stated that the seed price in Stage 1 is positively related to the per acre benefit i_1 that farmers obtain from adopting the new technology, and is negatively related to the farmer's seed reproduction cost. It is also positively related to the price of the existing public technology w^e and the marginal costs of seed production by the monopolistic life science company. The seed price and sales in Stage 2 are positively related to the price of the generic variety, farmers' reproduction costs, marginal costs of the seed company, and the innovation effort.

Substituting the optimal values for output and price gives the present value of the optimal profit stream:

$$\Pi^* = x_1^*(i_1)(w_1^{n*}(i_1) - c) + \delta x_2^*(i_1)(w_2^{n*}(i_1) - c).$$

3.3.3 Stage 0: R&D Decision of the Seed Developer Under PBRs

It is assumed that the cost of innovation (R&D outlay) is a function of the variety improvement, i_1: $TC(i_1) = \frac{(i_1)^2}{2}$. Thus, the firm chooses i_1 to maximize:

$$\max_{i_1} \Pi_0^* = \Pi^*(i_1) - \frac{(i_1)^2}{2}.$$

This yields the optimal innovation effort:

$$i_1^* = \frac{(4\lambda + 4\lambda\delta + 4k\delta + \lambda\delta^2)(w^e - c) - (4\lambda + 2k\delta)(c^r - \delta c)}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}, \tag{3.18}$$

where $2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2 \geq 0$ by second order conditions.

Given the optimal innovation effort, the optimal solutions in Stage 1 and 2 are as follows.

The seed supply in Stage 1 is:

$$x_1^* = \frac{(4\lambda + 2k\delta)(w^e - c) - (4\lambda - 2\delta)(c^r - \delta c)}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}. \tag{3.19}$$

The seed supply in Stage 2 is given by:

$$x_2^* = \frac{(2\lambda + \delta\lambda + 2k - k\delta)(w^e - c) + (2\lambda - 2k - \delta - 2)(c^r - \delta c)}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}. \tag{3.20}$$

As farmers' reproduction costs increase the profits from adopting the new technology and producing their own seed in Stage 1 decline, thus causing more farmers to wait until Stage 2 to purchase the new variety. Therefore, the higher the reproduction costs the higher the demand for seed in Stage 2. This places restrictions on the parameter values such that $(2\lambda - 2k - \delta - 2) > 0$.

The pricing strategy of the seed company in Stage 1 is given by equation 3.21:

$$w_1^* = \frac{(4\lambda^2 + 4\lambda^2\delta + \delta^2\lambda^2 - 2\delta k^2 - \delta^2 k\lambda)w^e + (2\delta k^2 + 2k\delta - 2k\delta\lambda - 4\lambda^2)c^r - Ac}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}, \tag{3.21}$$

where $A = \delta^2\lambda^2 - 2\delta\lambda^2 - 4\lambda^2 + \delta^2\lambda + 4\delta\lambda - 3k\delta^2\lambda + 4\lambda + 2\delta^2 k^2 + 2k\delta^2 + 4\delta k$.

The seed price in Stage 2 is:

$$w_2^* = \frac{\lambda(\delta\lambda + 2\lambda - k\delta + 2k)w^e + \lambda(2\lambda - \delta - 2k - 2)c^r - Dc}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}, \tag{3.22}$$

where $D = \delta\lambda^2 - 6\lambda^2 + 2\lambda\delta + 4\lambda + 2k^2\delta + 2k\lambda + 4k\delta - 3\lambda\delta k$.

Proposition 3.1. *The seed price charged by the monopolistic seed company in Stage 2 will be higher than the price in Stage 1 if the following condition holds:*

$$\frac{\delta^2\lambda^2 + 3\delta\lambda^2 + 2\lambda^2 - \delta^2 k\lambda + \delta k\lambda - 2k\lambda - 2\delta k^2}{6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k} \leq \frac{(c^r - \delta c)}{(w^e - c)} \leq \frac{4\lambda + 2k\delta}{4\lambda - 2\delta}.$$

Proof. The difference in the seed price charged by the seed company is:

$$\begin{aligned} w_2^* - w_1^* &= \frac{(c - w_e)[\delta^2\lambda^2 + 3\delta\lambda^2 + 2\lambda^2 - \delta^2 k\lambda + \delta k\lambda - 2k\delta - 2\delta k^2]}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2} \\ &+ \frac{(c^r - \delta c)[6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k]}{2(4\lambda^2 + \delta\lambda^2 - k^2\delta) - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2}. \end{aligned}$$

Given the assumption that $c < w^e$ the first element on the right-hand side of the equation is negative. Therefore, for the difference to be positive the second element should be positive and exceed the first element in magnitude. Using the second order condition it can be shown that $(6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2k\delta) \geq 0$. Thus, $w_2 \geq w_1$, but only if

$$(c^r - \delta c) \geq \frac{(w^e - c)[\delta^2\lambda^2 + 3\delta\lambda^2 + 2\lambda^2 - \delta^2 k\lambda + \delta k\lambda - 2\lambda k - 2\delta k^2]}{[6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k]} \geq 0. \tag{3.23}$$

The pricing strategy of the seed company should be such that the demand for seed in Stage 1 and Stage 2 is non-negative. For the first period demand to be non-negative the following condition should be satisfied:

$$(c^r - \delta c) \leq \frac{(4\lambda + 2k\delta)(w^e - c)}{(4\lambda - 2\delta)}. \tag{3.24}$$

While the first period sales are higher when reproduction costs are lower, the second period seed sales are higher when reproduction costs are higher. More specifically, to ensure positive seed demand in Stage 2 reproduction costs must be high enough such that

$$(c^r - \delta c) \geq \frac{(2\lambda + \delta\lambda + 2k - k\delta)(w^e - c)}{(2k + \delta + 2 - 2\lambda)}. \tag{3.25}$$

Because $(2k + \delta + 2 - 2\lambda) < 0$, the whole term on the right-hand side of (3.25) is negative. Therefore, while it is still possible for second period sales to be positive when reproduction of seed by farmers is more efficient than that by the seed company ($c^r < \delta c$), sufficiently low reproduction costs will drive to zero the seed demand in Stage 2.

Comparing the right-hand sides of (3.23) and (3.24) yields:

$$\begin{aligned} Dif &= \frac{(4\lambda + 2k\delta)}{(4\lambda - 2\delta)} - \frac{(\delta^2\lambda^2 + 3\delta\lambda^2 + 2\lambda^2 - \delta^2 k\lambda + \delta k\lambda - 2k\lambda - 2\delta k^2)}{(6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k)} \\ &= \frac{2(\delta k + \lambda - \delta\lambda)(8\lambda^2 + 2\delta\lambda^2 - 2\delta k^2 - 4\delta\lambda - 4\lambda - 4\delta k - \delta^2\lambda)}{(4\lambda - 2\delta)(6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k)} \geq 0. \end{aligned} \tag{3.26}$$

Combining (3.23), (3.24) and (3.26) gives the boundaries for farmers' reproduction costs such that the optimal strategy for the seed company is to charge a higher price in Stage 2. More specifically,

$$\frac{\delta^2\lambda^2 + 3\delta\lambda^2 + 2\lambda^2 - \delta^2 k\lambda + \delta k\lambda - 2k\lambda - 2\delta k^2}{6\lambda^2 - \delta\lambda + 2\delta k\lambda - 2k\lambda - 2\lambda - 2\delta k^2 - 2\delta k} \leq \frac{(c^r - \delta c)}{(w^e - c)} \leq \frac{4\lambda + 2k\delta}{4\lambda - 2\delta}. \tag{3.27}$$

□

As mentioned in previous sections of this chapter, seed has a durable aspect. The literature on durable goods argues that over time the monopolist seller will have strong incentive to reduce price. Anticipating this behaviour, the buyers will wait for the next period's lower price, which will drive down today's sales and price, thus undermining the ability of the monopolist to capture the rents. The presence of reproduction costs changes the nature of the problem, and it is possible to have a situation where the monopolist will have an incentive to charge a *higher* future price. However, if seed reproduction were costless to farmers ($c^r = 0$) then the second period price would always be lower then the first period price, and the result would be the one found in the durable good literature.[2] But because seed, unlike other durable goods, has to be reproduced to yield a stream of services in subsequent periods, a reverse result may be achieved. Therefore, Coase's conjecture can be eliminated if reproduction costs are high enough.

An interesting economic question concerns the factors that allow the seed company to charge a higher price in Stage 2. Basic intuition suggests that if farmers expect a higher price in the future they would purchase the seed today at a lower price and have their own seed for subsequent production. Diagrammatically, the result is shown in Figure 3.3. When the seed price in Stage 2 increases, the benefit from waiting and adopting the new technology in

[2]Without reproduction costs the seed price difference is: $w_2^* - w_1^* = \frac{(c-w^e)[\delta^2\lambda^2+3\delta\lambda^2+2\lambda^2-\delta^2 k\lambda+\delta k\lambda-2k\lambda-2\delta k^2]-\delta c[6\lambda^2-\delta\lambda+2\delta k\lambda-2k\lambda-2\lambda-2k^2\delta-2k\delta]}{2(4\lambda^2+\delta\lambda^2-k^2\delta)-4\lambda-4\lambda\delta-4\delta k-\lambda\delta^2} \leq 0$ for all parameter values that satisfy the second order conditions for profit maximization

the second period declines. In Figure 3.3, an increase in Stage 2's price is reflected in a shift of the profit curve π^{en} down to $\pi^{en'}$ and is accompanied by a reduction in the second period seed demand from $a^{no}a^{en}$ to $a^{en**}a^{en*}$. If the seed company increased the second period seed price too greatly, such that the profit curve $\pi^{en'}$ intersects π^{ee} to the left of point b, then the farmers would purchase the seed in Stage 1 and there would be no demand in Stage 2. It has been shown before that farmers will be willing to purchase the seed in Stage 2 only if $w_1^n - (\frac{\lambda}{\lambda-k} + \delta) > (i_1 + w^e - c^r)$, implying that in the absence of reproduction costs and $w_2^n > w_1^n$, all adopting farmers would purchase the seed in Stage 1 and produce their own seed for subsequent years.

Costly reproduction, however, makes it suboptimal for some farmers to reproduce the seed. An increase in farmers' reproduction costs shifts π^{no} down to $\pi^{no'}$, thus reducing the first period demand from a^{no} to a^{no**}, and increasing the second period demand to $a^{no**}a^{en}$. If reproduction costs are sufficiently high, no farmers will be willing to purchase and reproduce the seed. Therefore, for the adoption of the new technology to be attractive to some farmers in Stage 1, reproduction costs must be below a specific threshold, which is the condition on the right-hand side of (3.27). These costs must not be too low, however. Higher reproduction costs make the adoption of the new technology in Stage 2 more attractive, thus creating an incentive for the seed company to charge a higher price in Stage 2 without eroding the demand for seed. This condition is captured by the left-hand side of (3.27).

This section has considered the pricing strategy of the seed developer when farmers are permitted to save the seed under the farmer's exemption clause of PBRs. When farmers' costs of reproducing the seed are sufficiently low, the seed developer will behave as a durable good monopolist and have an incentive to reduce the price over time to attract non-adopters. If the reproduction costs are sufficiently high, the opposite result is possible, with the seed developer increasing the seed price over time.

The next section looks at the pricing strategy of the seed developer when the new technology is protected by patents, and is followed by a discussion of welfare and the R&D implications of the farmer's exemption.

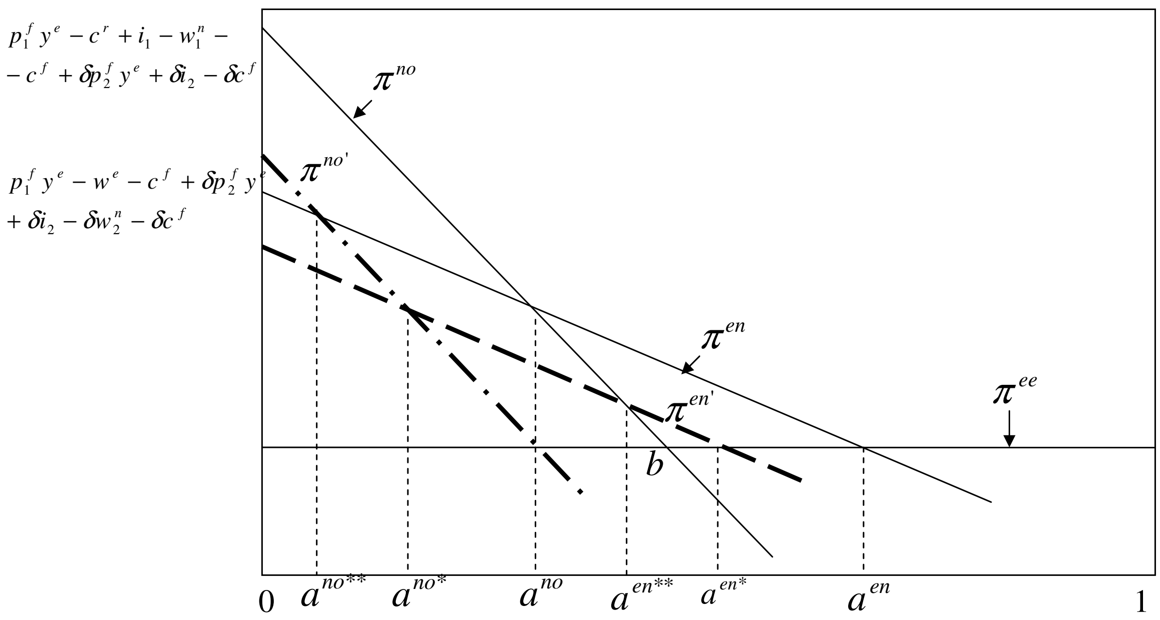


Figure 3.3: Farmer's adoption decisions, reproduction costs, and the seed price

3.4 The Benefits from Research when Patenting is Applied: Theoretical Model

As mentioned above, Canadian law does not allow the patenting of plant varieties. Patenting of the within-cell processes or the processes of splicing genes and inserting them into cells is allowed, however, and provides de facto protection of the whole plant. Furthermore, in order to protect intellectual property, seed companies have introduced Technical Use Agreements, which have been widely used in the Canadian canola sector over the last few years. When farmers buy new seed protected by this IP system, they must pay a technology use fee and sign contracts with the distributing company that prohibits saving progeny seed. Thus, in contrast to the case where a variety is protected by the plant variety certificate or a PBR, the farmer has to buy the innovated seed each year, which eliminates the durable aspect of the seed. It should also be noted that UPOV-91, in contrast to the earlier revisions, does not stipulate that farmers are given an automatic right to save harvested seed for re-planting, but rather whether to allow or disallow the use of harvested seed for subsequent reproduction is at the discretion of individual countries. Thus, if Canada implements UPOV-91 but does not allow farmers to save the seed, then the model described in this section will be applicable.

As in the case of PBRs, solving the game proceeds by backward induction. The solution at Stage 2 is found first. Then Stage 1 pricing and adoption decisions are solved for. A solution for optimal R&D effort is found last.

3.4.1 Stage 2: Adoption and Pricing Decisions Under Patents

Farm Sector

In Stage 2, both early and late adopters have to purchase seed from the seed company and, therefore, incur the per acre seed cost of w_2^n. Per acre profit for those farmers who adopt the new technology in Stage 2 is:

$\pi_2^n = p_2^f y^e + i_1 + kx_1 - w_2^n - c^f - \lambda a.$

When the existing generic variety is seeded in Stage 2 the profit is:

$\pi_2^e = p_2^f y^e - w^e - c^f.$

The choice for farmers is represented in Figure 3.4. In contrast to the case where the technology is protected by PBRs, patent protection guarantees that the seed demand in the second period comes also from early adopters. Therefore, the demand for seed is given by a^{en}.

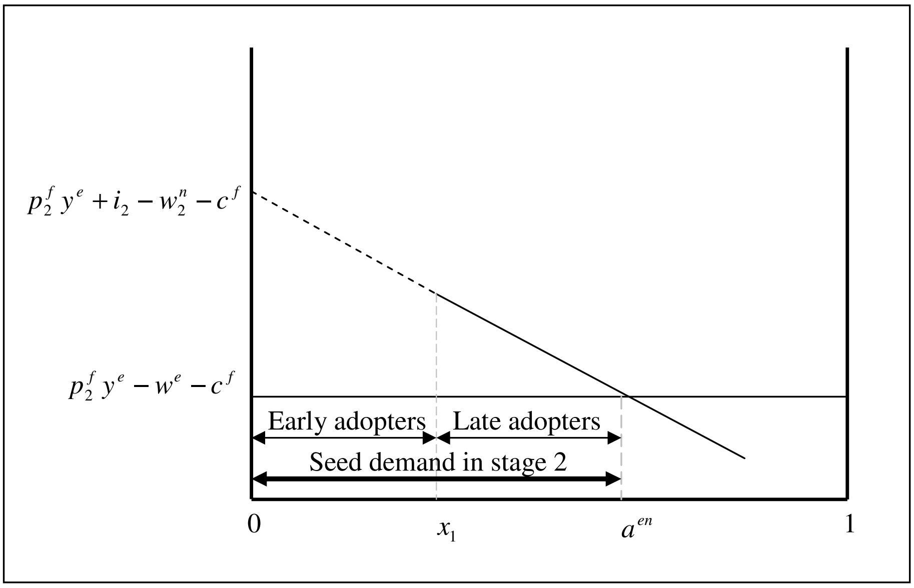


Figure 3.4: Stage 2 - Farmers planting decisions under patents

The marginal type of a farmer who is indifferent between planting the new or traditional technology is found by equating π_2^e and π_2^n. It gives the demand for seed the seed company faces in Stage 2:

$$a^{en} = x_2 = \frac{i_1 + kx_1 - w_2^n + w^e}{\lambda}. \tag{3.28}$$

In order to observe some adoption over time, it is crucial to include learning into the model, where the benefits in Stage 2 are positively related to the area under the new technology in Stage 1. If learning is not included, then, due to the fact that farmers have to buy the seed from the seed company every period, its profit maximization problem is reduced to a sequence of single-period optimizations in which the seed company does not discriminate between periods and sets the same price from year to year. The area under the new technology, then, remains the same over time.

In contrast to the equation for the first period seed demand under PBRs ((3.2)) that negatively relates seed sales in Stage 1 to seed sales in Stage 2, equation 3.28 shows that seed sales under patents in Stage 1 attract more demand in Stage 2 as knowledge about the new technology reaches more farmers.

Seed Developer's Problem

The seed company maximizes the profit in Stage 2 by choosing the sales quantity and the price:

$$\max_{x_2} \Pi_2 = (w_2^n - c)x_2 = x_2(i_1 + kx_1 + w^e - \lambda x_2 - c),$$

which yields the following solutions in Stage 2:

$$x_2^* = \frac{i_1 + kx_1 + w^e - c}{2\lambda}, \tag{3.29}$$

and

$$w_2^{n*} = \frac{i_1 + kx_1 + w^e + c}{2}, \tag{3.30}$$

and

$$\Pi_2^* = \frac{(i_1 + kx_1 + w^e - c)^2}{4\lambda}.$$

3.4.2 Stage 1: Adoption and Pricing Decisions Under Patents

Farm Sector

In Stage 1, only a portion of farmers adopt the new technology. Again, it is assumed that farmers will not switch back to the traditional technology in Stage 2 if they have already tried the new technology. Thus, there are three groups of farmers: (1) those who adhere to the existing public variety in both stages; (2) those who plant the traditional variety in Stage 1 and switch to the new variety in Stage 2; and (3) those who use the new technology throughout the game.

The present value of profits for the three groups of farmers is:

(1) Farmers who adopt the existing technology in both stages

$$\pi^{ee} = p_1^f y^e - w^e - c^f + \delta p_2^f y^e - \delta w^e - \delta c^f. \tag{3.31}$$

(2) Farmers who adopt the existing technology in Stage 1 and the new technology in Stage 2

$$\pi^{en} = p_1^f y^e - w^e - c^f + \delta p_2^f y^e + \delta i_1 + \delta k x_1 - \delta w_2^n - \delta c^f - \delta \lambda a. \tag{3.32}$$

(3) Farmers who adopt the new technology in both stages

$$\pi^{nn} = p_1^f y^e + i_1 - w_1^n - c^f - \lambda a + \delta p_2^f y^e + \delta i_1 + \delta k x_1 - \delta w_2^n - \delta c^f - \delta \lambda a. \tag{3.33}$$

Farmers will adopt the new technology in Stage 1 if the present value of the profit earned when the new variety is seeded in both stages is at least as great as the discounted return from using traditional seed in Stage 1 and the new seed in Stage 2. Equating π^{nn} and π^{en} yields the marginal type of the farmer who is indifferent between purchasing the new variety in Stage 1 and waiting until the next stage. Thus, the demand for the innovated seed in Stage 1 is:

$$a^{nn} = x_1 = \frac{i_1 + (w^e - w_1^n)}{\lambda}. \tag{3.34}$$

The equation indicates that sales of the new variety are positive only if the expected benefit from the new technology is greater than the difference between the price of the generic and the new variety. Under PBRs, farmers incorporate into their Stage 1 decisions the monopolist's

Stage 2 pricing strategy, but under patents the first period seed demand is no longer a function of the future pricing strategy of the seed developer.

Seed Company's Problem

Going back to Stage 1, the seed company is aware of the fact that the choice made in the first period will effect the second period profit. Thus, it maximizes the present value of profit:

$$\max_{x_1} \Pi = (i_1 + w^e - \lambda x_1 - c)x_1 + \frac{\delta(i_1 + kx_1 + w^e - c)^2}{4\lambda}.$$

To ensure the concavity of the profit function the following condition must hold: $4\lambda^2 - \delta k^2 > 0$.

The optimal sales quantities and prices are:

$$x_1^* = \frac{(2\lambda + \delta k)(i_1 + w^e - c)}{4\lambda^2 - k^2\delta}, \tag{3.35}$$

and

$$x_2^* = \frac{(2\lambda + k)(i_1 + w^e - c)}{4\lambda^2 - k^2\delta}, \tag{3.36}$$

and

$$w_1^{n*} = \frac{(2\lambda^2 - k^2\delta - k\lambda\delta)(i_1 + w^e) + (2\lambda^2 + k\lambda\delta)c}{4\lambda^2 - k^2\delta}, \tag{3.37}$$

and

$$w_2^{n*} = \frac{(2\lambda^2 + k\lambda)(i_1 + w^e) + (2\lambda^2 - k^2\delta - k\lambda)c}{4\lambda^2 - k^2\delta}. \tag{3.38}$$

From the above equations, it is evident that as long as $k > 0$ and $\delta < 1$ the sales of the innovated seed in Stage 2 will be larger than in Stage 1. The above equations can be used to derive the following proposition.

Proposition 3.2. *When the technology is protected by patents and there is learning going on, the seed company will charge a lower price in Stage 1.*

Proof. The difference between the third and second stage prices is $w_2^{n*} - w_1^{n*} = (k\lambda + k^2\delta + k\lambda\delta)(i_1 + w^e - c)$. For the first period demand to be positive, the following condition should hold: $w_1^n < (i_1 + w^e)$, that is, the price for the innovated seed should be less than the price of the available public variety plus the benefit the new variety yields. As a monopolist, the seed company will exercise the above marginal cost pricing implying that $w_1^{n*} > c$. Therefore, $i_1 + w^e > c$ and, consequently, $w_2^{n*} - w_1^{n*} > 0$. □

The profits earned by the seed company over the two periods are:

$$\Pi^* = \frac{((2\lambda^2 - k^2\delta - k\lambda\delta)(2\lambda + k\delta) + \delta\lambda(2\lambda + k)^2)(i_1 + w^e - c)^2}{(4\lambda^2 - k^2\delta)^2}$$

3.4.3 Stage 0: R&D Decisions Under Patents

Assuming that the cost of innovation is $TC(i_1) = \frac{i_1^2}{2}$, the innovation effort by the seed company is found from

$$\max_{i_1} \Pi_0 = \Pi^* - \frac{i_1^2}{2}.$$

The solution to this problem is:

$$i_1^* = \frac{2(\lambda + k\delta + \delta\lambda)(w^e - c)}{4\lambda^2 - \delta k^2 - 2\lambda - 2\delta\lambda - 2k\delta}. \tag{3.39}$$

Proposition 3.3. *Patents do not guarantee better varieties. If seed production costs for the seed company are at least equal to the price of the generic variety, then the company will not invest in R&D.*

Proof. The right-hand side of equation 3.39 is positive only if $(w^e - c) > 0$. Therefore, for the monopolistic firm to have an incentive to innovate, its seed production must be more efficient than that of the generic variety. □

An immediate implication of the above proposition is that patents can encourage varietal development if they encourage process innovation so that marginal costs are reduced.

Substituting the optimal innovation effort into the sales and price equations gives the equilibrium quantities of seed in each period and the price the seed company charges.

$$x_1^* = \frac{(2\lambda + \delta k)(w^e - c)}{4\lambda^2 - k^2\delta - 2\lambda - 2\lambda\delta - 2k\delta}, \tag{3.40}$$

and

$$x_2^* = \frac{(2\lambda + k)(w^e - c)}{4\lambda^2 - k^2\delta - 2\lambda - 2\lambda\delta - 2k\delta}, \tag{3.41}$$

and

$$w_1^* = \frac{(2\lambda^2 - k^2\delta - k\delta\lambda)w^e + (2\lambda^2 - 2\lambda\delta - 2\lambda - 2k\delta + k\delta\lambda)c}{4\lambda^2 - k^2\delta - 2\lambda - 2\lambda\delta - 2k\delta}, \tag{3.42}$$

and

$$w_2^* = \frac{(2\lambda^2 + k\lambda)w^e + (2\lambda^2 - 2\lambda - 2\delta\lambda - 2k\delta - k^2\delta - k\lambda)c}{4\lambda^2 - k^2\delta - 2\lambda - 2\lambda\delta - 2k\delta}. \tag{3.43}$$

The pricing strategy of the monopolistic seed developer is constrained by the existence of the generic variety. The highest price that the monopolist will be able to charge is the price of the generic variety. As can be seen from the above equations, the optimal price is a weighted average of the price of the generic variety and the marginal costs.

3.5 Innovation Effort and Welfare Implications: Plant Breeder's Rights versus Patents

The welfare of farmers is illustrated in Figure 3.5. In Figure 3.5 the grey area $0AF1$ represents the farmer's surplus from using the generic variety. Obviously, only those farmers who adopt the new technology in at least one period reap the benefits. The early adopters enjoy the benefits given by $ABCD$, while the late adopters' surplus is represented by DCE. The farmers' welfare is thus the sum of these areas. Since it is assumed that the product price received by farmers is exogenously given and, therefore, the demand is represented by a flat line the consumer surplus is zero. Therefore, the social welfare is the sum of farmers' benefits and the seed company's profits.

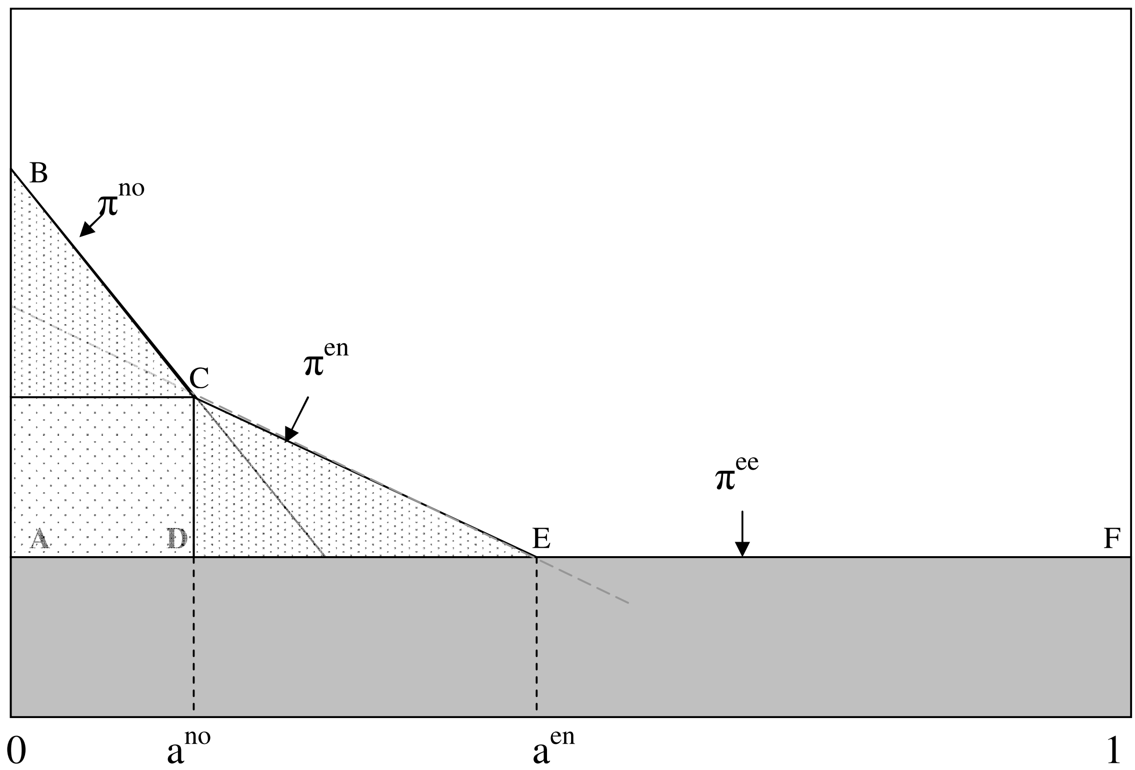


Figure 3.5: Adoption of the new technology and farmer's welfare

Table 3.1 reports the simulation results. The parameters were chosen such that the second order conditions for profit maximization hold. Furthermore, to ensure that the market share for the new technology lies within the [0,1] range, the following condition should hold: $a^{en} < 1$ (see Figure 3.2), which restricts the value of λ to being greater than $i_1^* + kx_1^* - w_2^* + w^e$. The marginal costs of seed production were chosen so that the production of seed in the first period is positive and the necessary condition is that $c < w^e$.

The first column presents the parameter values. To see the welfare impacts, the parameter values are changed one by one, and the parameters being changed are bolded. The following propositions are reached:

Proposition 3.4. *Seed company's profit, farmers' welfare and total welfare decline as the parameter λ becomes larger.*

An increase in the costs associated with the adoption of the new technology (captured by the parameter λ) pivots the farmers' profit functions π^{no} and π^{en} inwards, thus reducing the demand for the innovated seed and farmers' surplus in both periods. Therefore, an increase in λ shifts the demand curve faced by the seed developer, D, downward to D' (Figure 3.6). This leads to lower seed sales and a lower price $w_1^{n'}$ as compared to w_1^n, thus driving seed sales revenue down.

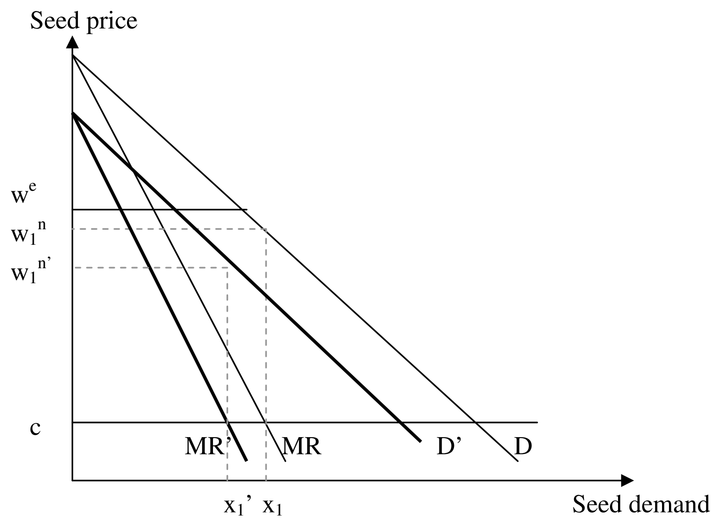


Figure 3.6: Changes in seed demand and price due to an increase in the parameter λ

Table 3.1: *Welfare under PBRs and patents: simulation results*

Parameters							PBRs					Patents				
λ	δ	k	w^e	c	c^r	y	$i*$	Seed company's profit	Farmer's welfare	Total welfare (TW)	ΔTW[1]	$i*$	Seed company's profit	Farmer's welfare	Total welfare (TW)	ΔTW
10	0.95	0.1	13	5	7	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial \lambda} < 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial \lambda} < 0$
12	0.95	0.1	13	5	7	35	0.55	1.97	1.50	3.47		0.71	2.84	1.55	4.39	
14	0.95	0.1	13	5	7	35	0.47	1.67	1.26	2.93		0.60	2.40	1.30	3.70	
16	0.95	0.1	13	5	7	35	0.41	1.45	1.08	2.53		0.52	2.08	1.11	3.19	
10	**0.95**	0.1	13	5	7	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial \delta} < 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial \delta} < 0$
10	**0.90**	0.1	13	5	7	35	0.64	2.25	1.73	3.98		0.84	3.38	1.88	5.26	
10	**0.85**	0.1	13	5	7	35	0.61	2.11	1.60	3.71		0.82	3.28	1.82	5.10	
10	**0.80**	0.1	13	5	7	35	0.58	1.96	1.47	3.43		0.80	3.18	1.76	4.94	
10	0.95	**0.1**	13	5	7	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial k} > 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial k} > 0$
10	0.95	**0.2**	13	5	7	35	0.68	2.42	1.88	4.30		0.88	3.50	1.96	5.46	
10	0.95	**0.3**	13	5	7	35	0.68	2.43	1.90	4.33		0.88	3.51	1.98	5.49	
10	0.95	**0.4**	13	5	7	35	0.68	2.44	1.91	4.35		0.88	3.53	2.00	5.53	
10	0.95	0.1	**13**	5	7	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial w^e} > 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial w^e} > 0$
10	0.95	0.1	**14**	5	7	35	0.77	3.13	2.43	5.56		0.98	4.40	2.45	6.85	
10	0.95	0.1	**15**	5	7	35	0.87	3.95	***3.08***	7.03		1.09	5.43	***3.03***	8.46	
10	0.95	0.1	**16**	5	7	35	0.97	4.86	***3.80***	8.66		1.19	6.57	***3.66***	10.23	
10	0.95	0.1	13	**5**	7	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial c} < 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial c} < 0$
10	0.95	0.1	13	**7**	7	35	0.57	1.65	***1.31***	2.96		0.65	1.96	***1.09***	3.05	
10	0.95	0.1	13	**9**	7	35	***0.46***	***1.10***	***0.86***	1.96		***0.43***	***0.87***	***0.48***	1.35	
10	0.95	0.1	13	**11**	7	35	***0.35***	***0.75***	***0.54***	1.29		***0.22***	***0.22***	***0.12***	0.34	
10	0.95	0.1	13	5	**7**	35	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial c^r} < 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial c^r} = 0$
10	0.95	0.1	13	5	**9**	35	0.59	1.97	1.43	3.40		0.87	3.48	1.94	5.42	
10	0.95	0.1	13	5	**11**	35	0.50	1.70	1.10	2.80		0.87	3.48	1.94	5.42	
10	0.95	0.1	13	5	**13**	35	0.41	1.60	0.86	2.46		0.87	3.48	1.94	5.42	
10	0.95	0.1	13	5	7	**35**	0.67	2.41	1.86	4.27	$\frac{\partial TW}{\partial y} = 0$	0.87	3.48	1.94	5.42	$\frac{\partial TW}{\partial y} = 0$
10	0.95	0.1	13	5	7	**40**	0.67	2.41	1.86	4.27		0.87	3.48	1.94	5.42	
10	0.95	0.1	13	5	7	**45**	0.67	2.41	1.86	4.27		0.87	3.48	1.94	5.42	
10	0.95	0.1	13	5	7	**50**	0.67	2.41	1.86	4.27		0.87	3.48	1.94	5.42	

[1] – Given the fixed output price the consumer surplus is zero.

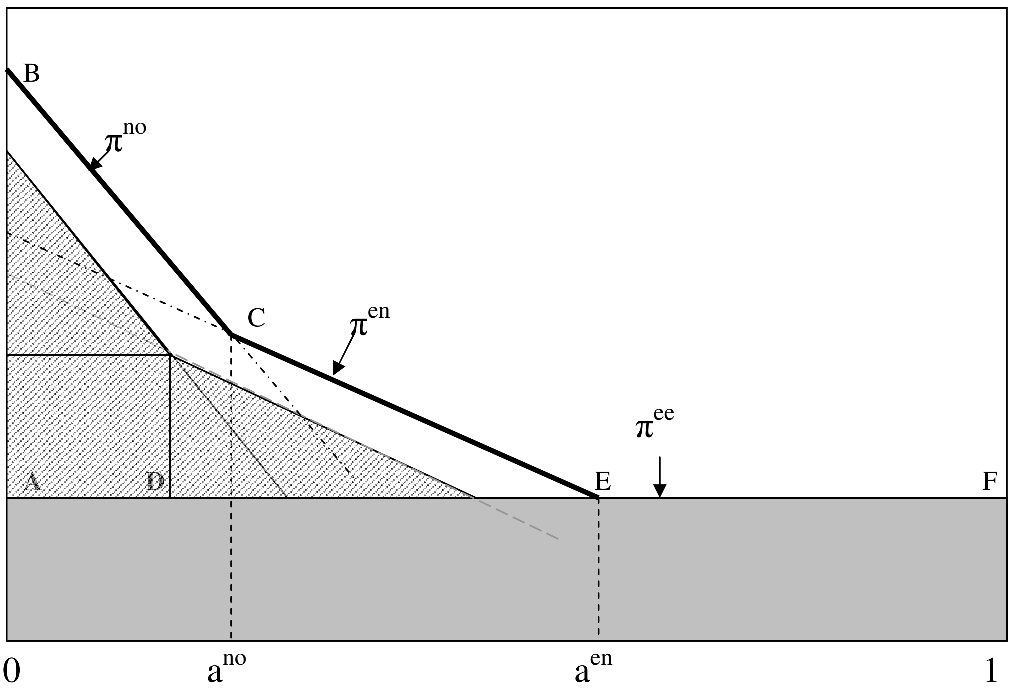


Figure 3.7: Change in the farmers' surplus as the costs of seed reproduction increase

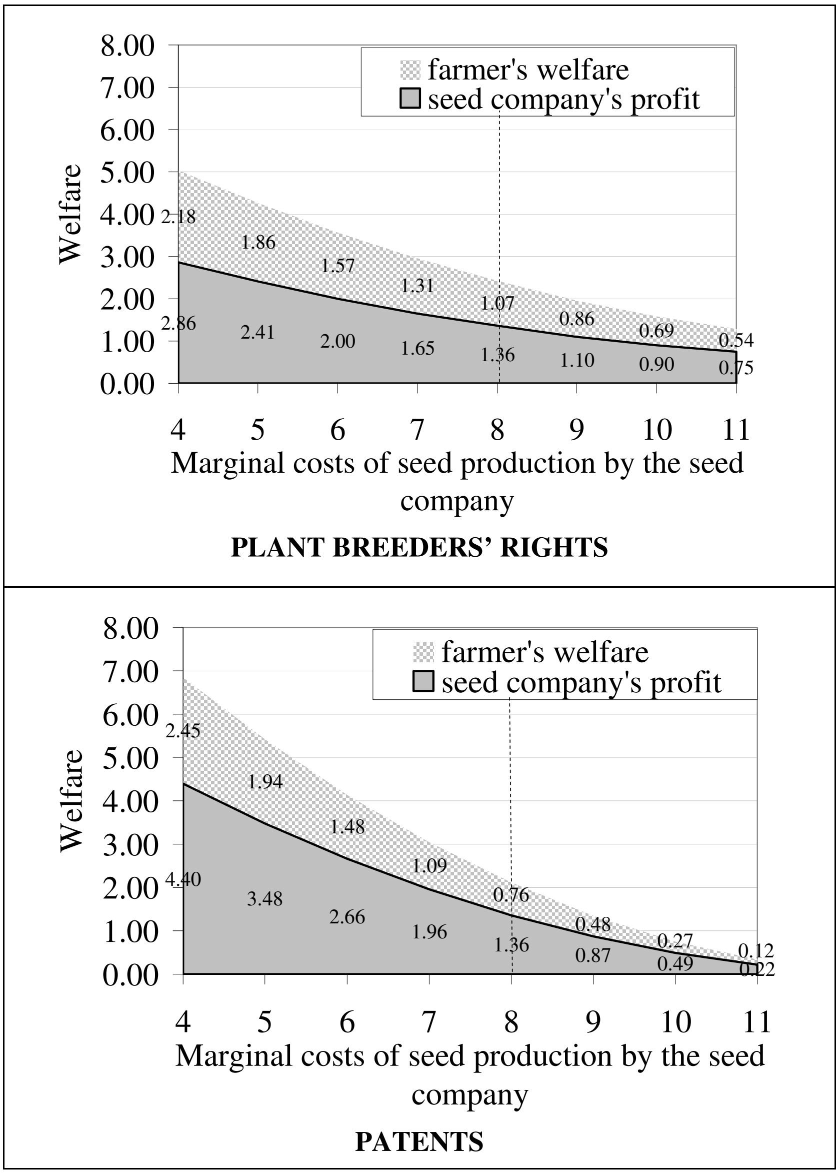
Proposition 3.5. *Farmers' welfare declines as the costs of saving (reproducing) the seed rise*

An increase in reproduction costs encourages farmers to delay the adoption of the new technology until Stage 2. Therefore, the adoption of the new technology and, the benefits from adopting the new technology in Stage 1 decline. Higher demand in Stage 2 allows the seed company to increase the price, which shifts π^{en} downward such that the new farmers' surplus is contained in the original surplus $ABCE$ (Figure 3.7).

The results in Table 3.1 and Figure 3.8 indicate that, in general, the total welfare is higher under patents, which is achieved primarily through an increase in the monopoly's rents. The only exception is the case where marginal costs for the seed company exceed reproduction costs by farmers. In such a case, *PBRs give better incentives to innovate* and, as a result, ensure higher profit for the seed company and higher farmer's welfare.

Proposition 3.6. *Innovation efforts under PBRs are higher than under patents when the following condition holds:*

$$\frac{\lambda\delta(2\lambda+\delta k)}{2(4\lambda^2-\delta k^2-2\lambda-2\delta\lambda-2k\delta)} < \frac{(\delta c-c^r)}{(w^e-c)} < \frac{(2\lambda+\delta\lambda+2k-k\delta)}{(2\lambda-2k-\delta-2)}.$$



Parameter values: $\lambda = 10$, $\delta = 0.95$, $k = 0.1$, $w^e = 13$ \$/acre, $c^r = 7$ \$/acre, $y = 35$ bushel/acre, $p = 4.41$\$/bushel

Source: Simulation results by author

Figure 3.8: Distribution of benefits from research for different level of seed production costs by the seed company: simulation results

Proof. The difference between the optimal innovation effort under patents, i^*_{patent}, and that under PBRs, i^*_{PBRs} is:

$$i^*_{patent} - i^*_{PBRs} = \frac{\lambda\delta(2\lambda+\delta k)^2(w^e - c) + (4\lambda + 2k\delta)(4\lambda^2 - \delta k^2 - 2\lambda - 2\delta\lambda - 2k\delta)(c^r - \delta c)}{(8\lambda^2 + 2\delta\lambda^2 - 2k^2\delta - 4\lambda - 4\lambda\delta - 4\delta k - \lambda\delta^2)(4\lambda^2 - \delta k^2 - 2\lambda - 2\delta\lambda - 2k\delta)}.$$

Therefore, $i^*_{patent} < i^*_{PBRs}$ when

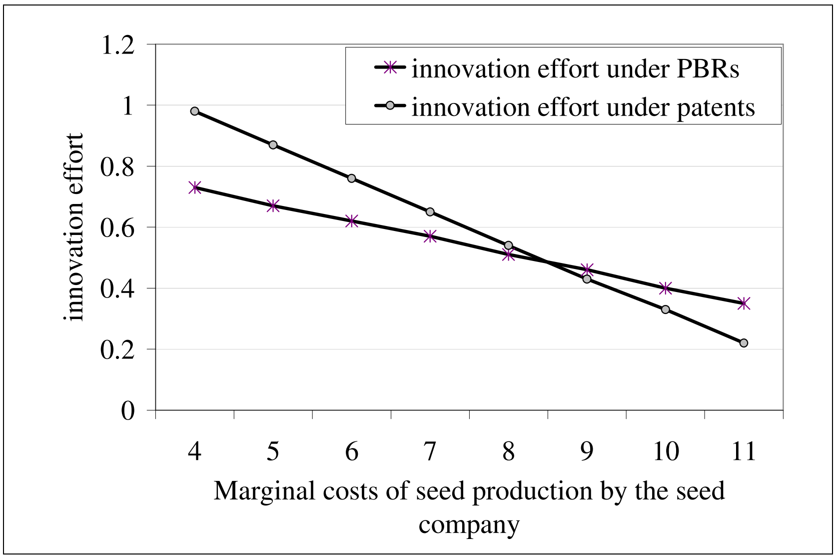
$$\frac{\delta c - c^r}{w^e - c} > \frac{\lambda\delta(2\lambda+\delta k)}{2(4\lambda^2 - \delta k^2 - 2\lambda - 2\delta\lambda - 2k\delta)} \geq 0. \tag{3.44}$$

The above equation indicates that PBRs are more efficient in encouraging innovation if the discounted marginal cost of seed production for the seed company exceeds the farmers' costs of reproducing the seed. Low reproduction costs (relative to marginal costs) will raise the demand for the seed in Stage 1 and lower the demand in Stage 2. For sufficiently low reproduction costs, all adopting farmers will choose to adopt the new technology in Stage 1. Therefore, a lower bound should be placed on the reproduction costs that would ensure non-negative second period seed sales. Using equation 3.25, Stage 2's sales are non-negative if

$$\frac{\delta c - c^r}{w^e - c} \leq \frac{2\lambda + \delta\lambda + 2k - k\delta}{(2\lambda - 2k - \delta - 2)}. \tag{3.45}$$

Combining (3.44) and (3.45) yields the inequality in Proposition 3.6. □

As Table 3.1 indicates generally patents tend to dominate PBRs in terms of both farmers' and seed developer's welfare due to higher innovation effort under patents. Under certain circumstances, however, PBRs are more effective in fostering innovation. For certain values of farmers' reproduction costs and marginal costs of seed production for the seed company, PBRs can create a better stimulus for varietal development. More specifically, higher marginal costs of seed production reduce innovation effort under PBRs, with a speed of reduction being higher under patents, thus narrowing the gap between innovation effort under PBRs and patents (Figure 3.9). When the discounted value of the marginal costs exceed farmers' reproduction costs, the innovation pattern changes, with PBRs providing more incentives to innovate. Linking this to Proposition 3.1, one can see that higher innovation effort and higher monopolist's profit occur apart from the ability of the seed developer to charge a higher price in Stage 2. The seed developer will charge a higher price in Stage 2 compared to the price in



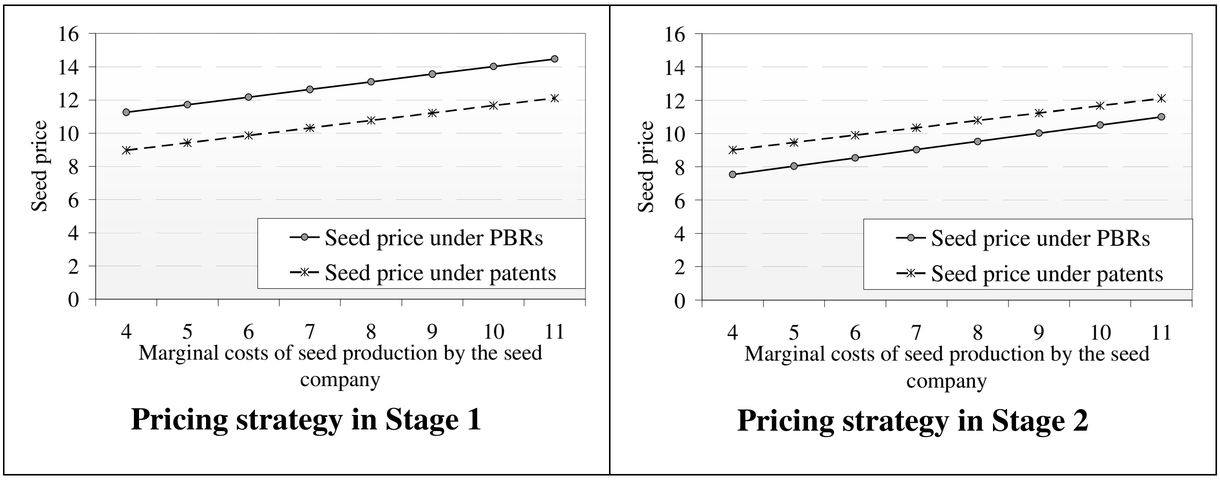
Parameter values: $\lambda = 10$, $\delta = 0.95$, $k = 0.1$, $w^e = 13$ \$/acre, $c^r = 7$ \$/acre, $y = 35$ bushel/acre, $p = 4.41$ \$/bushel

Source: Simulations by author

Figure 3.9: Innovation effort for different level of seed production costs by the seed company: simulation results

Stage 1 if farmers' reproduction costs are sufficiently high, while a necessary condition for the monopolist's profits to be higher under PBRs versus patents is that farmers' reproduction costs are sufficiently low relative to the seed company marginal production costs. The two regions specified in Proposition 3.1 and Proposition 3.6 do not overlap. When the condition specified in Proposition 3.6 holds the seed developer is better off under PBRs versus patents even though the pricing strategy is to reduce the seed price over time, which is a pattern claimed to lead to "Coase's conjecture" and the inability of the durable good monopolist to capture rents.

Figure 3.10 shows the pricing strategy of the monopolistic seed company under patents and PBRs. The results indicate that when the technology is protected by PBRs, the seed developer indirectly captures the value of the innovation by charging a high price on the parental seed. When farmers' reproduction costs are low relative to marginal costs, charging a higher price in Stage 1 and letting farmers reproduce the seed allows the seed developer to extract some portion of future benefits generated by saved seed and substitute his inefficient production for farmers' efficient reproduction. Thus, PBRs can yield higher profits to the seed company as they permit to take advantage of farmers' lower reproduction costs.



Source: Simulations by author

Figure 3.10: Pricing strategy of the seed developer under patents and PBRs: simulation results

As for the farmers' welfare, under the two regimes the simulation results show that under the patenting regime farmers capture around 36% of the total benefits, while under PBRs this share amounts to 44%. Thus, patents reduce the portion of benefits captured by farmers, even though in absolute terms farmers' welfare is not necessarily lower under patents. As the simulation results presented in Figure 3.8 suggest, for low marginal costs (below \$6) higher innovation efforts under patents translate into higher absolute gains for farmers.

3.6 Conclusions

In this chapter, a theoretical model has been developed that describes economic incentives under patents versus PBRs. The farmer's exemption provided for by PBRs make them essentially different from patents in the sense that seed can be purchased by farmers only once and then saved for subsequent periods, thus acquiring a durable aspect. Given this exemption, some believe that PBRs are an ineffective tool to stimulate R&D activity in the breeding sector. At the same time, there are concerns that even though patents are effective in inducing innovation, they prevent farmers from appropriating rents generated by the new technology.

The model's results suggest that one cannot unambiguously say that, from both a social and a farmer's point of view, patents are better than PBRs or vice versa. The simulation results reveal that under the patenting regime, farmers indeed capture a smaller share of total benefits, but, depending on the cost of seed production by the seed company and farmers' reproduction costs, farmers may nevertheless gain more under patents in absolute terms. As the marginal costs of seed production increase beyond farmers' reproduction costs, the seed company is better off protecting the technology with PBRs - that is, it is better off selling the technology to farmers and letting them reproduce it, thus substituting inefficient production for farmers' more efficient reproduction.

Chapter 4

INCENTIVES TO PROTECT AND SHARE DOWNSTREAM TECHNOLOGIES: A GAME THEORETIC APPROACH

4.1 Introduction

Prior to 1990, the publicly dominated crop-breeding sector was generally characterized by wide sharing of technologies and information among researchers. Over the last two decades, however, some seed industries have undergone significant transformations. Achievements in molecular science have allowed researchers to modify genes within cells and build in traits not available through traditional breeding. In addition to offering new traits, DNA modification techniques have allowed the development of new varieties at both a lower cost and faster pace, which has attracted private sector R&D investment. Associated with increased involvement of the private sector, there has been a parallel evolvement of a stronger intellectual property rights (IPRs) regime. In many countries, including Canada, patents have been granted for both plant traits and the "building blocks" used in plant breeding.

IPRs are intended to stimulate innovations in research industry. Due to the cumulative nature of crop research, however, there are increasing concerns that IPRs may slow down the innovation process and impose significant costs. Crop genetic research tends to be cumulative, and assigning property rights to research inputs such as germplasm, cultivars, gene sequences, and markers separates building blocks for a product or line of research. When these property rights are diffused among multiple owners, the negotiation process to put the required pieces of IP together may fail, thus leading to an exclusion of plant breeders from certain areas of research, quashing promising research initiatives, and delaying breakthroughs in research industry. This problem is especially acute in sectors where DNA modification techniques are used extensively. The developer of a transgenic plant needs trait specific genes, enabling technologies such as transformation technologies and promoters, as well as method patents. Developing a transgenic plant may require fifteen to forty identifiable tangible components (Lindner (1999)). Pioneer Hi-Bred's genetically engineered insect-resistant corn hybrid, for example, requires access to thirty-eight different patents that are controlled by sixteen separate patent holders (Shand (2002)). When too many intellectual assets are involved, negotiations may break down because each IP owner wants to extract a disproportionate share of rents. Heller and Eisenberg (1998) have labeled this problem as the "tragedy of anticommons."

The possibility of protecting research tools and final products is creating a number of controversies in the breeding sector. On the one hand, plant breeders are users of past achievements. As users, they benefit from cooperation and free access to upstream technologies and knowledge. On the other hand, breeders are also producers of knowledge. When researchers are driven by private incentives, enclosing information is beneficial for innovators because it ensures a scientific lead and a temporary monopolistic position in the final product markets. Keeping knowledge/technologies private also allows developers to increase profits by licensing their technologies to other firms. If private gains from knowledge enclosure outweigh the benefits from cooperation, there is an incentive for researchers to deviate from a cooperative equilibrium and make upstream technologies proprietary, which may give rise to the tragedy of anticommons.

The purpose of this chapter is to look into the incentives for private researchers to share their technologies when IP protection is available. The chapter is structured as follows. Section 4.2 contains a literature review of the effect of patenting upstream innovations on downstream research. Section 4.3 provides a game theoretic model to explain the incentives for private firms to protect their upstream innovations and implications for downstream research. Section 4.4 concludes the discussion.

4.2 Literature Review: IPRs in Cumulative Research Industry

The lack of intellectual property rights for common-pool goods and the associated "tragedy of the commons" was first introduced by Hardin (1968). He explains the tragedy of the commons as one that arises because, with no property rights defined, people have an incentive to overuse the common resource. He asserts that assigning (intellectual) property rights over the good could avert a tragedy of the commons. But, as Heller and Eisenberg (1998) suggest, while the assignment of property rights may solve the tragedy of the commons, it may subsequently cause another tragedy, termed the "tragedy of the anticommons." This arises when intellectual property rights are so diffuse among multiple owners that no one has an effective privilege to use the resource and the resource is wasted. Heller and Eisenberg indicate that as research industry is moving from a common model toward a privatization model, which is the observed trend in agricultural research, the tragedy of the anticommons becomes prevalent. The existence of multiple owners, each of whom has a right to exclude others from using a resource, can limit or block access to inputs necessary for conducting downstream research, thus stifling the innovation process.

Heller and Eisenberg (1998) identify three reasons why the negotiations over rights may break down. First, in most research projects licenses have to be bundled before the firm has an effective right to develop a new technology. If the research results are uncertain or the commercial value of the project is small, the costs of obtaining all necessary licenses may exceed the expected value of innovation and the project will not be undertaken. Second, heterogeneity of interests may generate conflicting agendas among right holders, which can make it difficult to reach an agreement among all negotiating parties. Third, the right owners may be biased in estimating the value of their inventions. If each patent holder overestimates the value and importance of their invention, then each will charge a price in excess of a probabilistic value of the invention. In this case, the total price that has to be paid to obtain inputs from multiple owners will be more than the market value, and bargaining will fail. The authors also suggest that even if a negotiation process is successful, legal agreements may limit the freedom to disseminate research outputs. They describe a case where DuPont Corporation offered some universities the use of their patented oncomouse and cre-lox technologies on license terms. The licenses offered required that the licensees receive DuPont's approval before any research results were commercialized. Being the owner of the upstream technology gave the corporation a right over downstream research and product development, thus limiting the freedom to operate for downstream research institutions, and incentives to pursue further research.

The existence of multiple IP owners makes the negotiation process more cumbersome and costly, and, therefore, erodes private incentives to conduct R&D. Obtaining access to multiple and diffuse IPs, however, is not the only reason why patents can impede innovation. A body of theoretical literature has emerged that emphasizes that, when technology is cumulative, firms may have incentives to keep early generation inventions for their self-interested use, in which case the existence of even one proprietary piece of IP can erode incentives for subsequent research (Merges and Nelson (1990), Scotchmer (1991), Denicolo (2000)).

Scotchmer (1991) argues that without prior licensing agreements, a patent on the first generation invention reduces the incentives of an outside firm to invest in the second generation invention. When the first generation invention provides benefits to later innovators in the form of reduced production costs or faster product development, for example, the first innovators will have correct incentives to invest only if they can capture some of the value generated by the second generation products. Therefore, some part of the surplus will have to be transferred from later innovators, thus reducing their incentives to invest. She further argues that unless the first generation innovator lacks capacity to develop the second generation product, there will be a strong incentive for the first innovator to engage in product development and keep the first generation invention private until a more valuable second generation product is developed and patented.

Denicolo (2000) develops a two-period model to examine research incentives. In the first period, the firms compete in R&D and one firm invents and patents a research tool that can be used in subsequent research. In the second period, innovation builds on the patented tool. Denicolo considers four scenarios: (1) the second invention is unpatentable and infringing; (2) the second invention is unpatentable and non-infringing; (3) the second invention is patentable and infringing; and (4) the second invention is patentable and non-infringing. The model yields that stronger protection of the upstream invention encourages more R&D effort into the first invention, but discourages R&D investment into the downstream invention in contrast to Kitch's (1977) finding, where stronger patents on upstream innovations prevent R&D duplication efforts and are, therefore, more attractive.

The revolution in molecular biology science and increasing application of IPRs in cumulative research industries, such as plant breeding and biomedical research, have made the patent system a matter of current debate and have inspired interest in empirical studies of the tragedy of anticommons.

Price (1999) has examined how widespread were the difficulties associated with obtaining protected genetic stock. The survey included twenty-five American universities and covered forty-one crops. Almost half the respondents (48%) indicated that they had difficulties in obtaining genetic stock from private companies - "45% indicated that this had interfered with their research; 28% felt that it had interfered with their ability to release new varieties, and a shocking 23% reported that it had interfered with the training of graduate students" (Price (1999)).

Walsch et al (2003) have looked into whether biomedical innovation suffers because of restrictions on the use of proprietary research tools necessary for subsequent research. The authors conducted seventy interviews with IP attorneys, business managers, and scientists from ten pharmaceutical and fifteen biotech firms, as well as with university researchers and technology transfer officers. They find that patenting increased over time and that about one-third of respondents indicated that they increased their patenting of research tools in response to increased patenting by others to ensure freedom to operate. As for the existence of a tragedy of the anticommons in biomedical research, the authors found no evidence of negotiation breakdowns, nor could the respondents identify a specific project that had to be stopped due to an inability to access research tools. The results also reveal that dealing with research tools patents does cause delays and that one-third of respondents considered the negotiation process as a lengthy and labour intensive process. While half the respondents complained about licensing costs respondents did not identify royalty stacking as a significant threat to ongoing R&D projects. While large companies did not consider license fees a hindrance, small start-ups reported them to be prohibitive.

To summarize, there is evidence that patent protection of research inputs slows down the research process in industries where innovation is cumulative. But why do firms choose to patent and restrict access to their discoveries in the first place? Past experience in the Canadian plant breeding industry suggests that free sharing of information is beneficial for all breeders. Without cooperation among researchers, edible canola, for example, would have never been developed, and the wheat sector would have never achieved today's levels. An important question, then, is why firms enclose their knowledge and how the cooperative equilibrium can be sustained in the world of IP protection. This issue is addressed in the following section.

4.3 Sharing of Technologies Within the Private Industry: a Theoretical Framework

In a private agricultural research industry, companies conduct R&D in similar areas and compete on the market for final products (i.e., plant varieties). The overlapping nature of research makes firms aware of the importance of making the best use of created knowledge before it is revealed to rivals. On the one hand, enclosing knowledge allows a firm to take a scientific lead in the market and enjoy a temporary monopoly power. On the other hand, however, if a firm is not self-sufficient in technologies required to develop a product, enclosing knowledge can limit a firm's ability to access knowledge held by others. Therefore, pricing of upstream innovations and the decision whether to share the developed technologies with firms competing in the same field are strategic choice variables of the seed companies.

At this point, game theory is applied to understand the incentives for firms to protect their technologies or license the technology to their rivals on the output market, or maintain exclusive rights. The model developed in what follows is closely linked to the tragedy of anticommons. The key assumption made by Heller and Eisenberg (1998) that can lead to the tragedy of anticommons is that inputs that go into research process are essential. To put it in other words, it is assumed n pieces of IP have to be combined in order to produce research output and if it at least one piece of IP cannot be obtained no output is produced and the R&D resources are wasted. This work is linked to but differs from the tragedy of anticommons as defined by Heller and Eisenberg (1998) as it is assumed that there is a pathway to research. When one firm cannot access research inputs owned by the rival firm this particular pathway is blocked. However, the firm can take an alternative route and design the missing IPs, but the amount of resources required to do that will be higher than that spent by the rival firm that owns the original IPs.

There are two private firms, A and B. Looking into the behaviour of *private* firms can provide useful insights into possible developments in the crop research industry as it moves towards privatization. The model described in what follows is valuable for studying the incentives to share research inputs within private industry. As public support to crop research declines, however, *public* researchers become more concerned about revenues and are encouraged to enter collaborative agreements with the private sector to supplement public funds. Collaboration with private industry can change the behaviour of public scientists, so that R&D efforts are driven by private rather than social incentives. In this light, this model is not confined to the behaviour of private firms, but can also capture the incentives for public researchers.

The game is set up in four stages (described in Figure 4.1). Firms develop research inputs (production technologies), and in Stage 1 they decide whether to place their technologies into public domain or protect them. At this stage, there are four potential outcomes: (1) both firms make their technologies publicly available (the box in the top left-hand corner); (2) Firm A places the technology into the public domain and Firm B protects its technology (the box in the top right-hand corner); (3) Firm A protects its technology and Firm B makes its publicly available (the box in the bottom left-hand corner); and (4) both firms apply some form of IPR on their technologies (the box in the bottom right-hand corner). If some form of IP protection is placed on research inputs, a firm proceeds to Stage 2 and makes a decision whether to license the technology to the other firm or maintain an exclusive right over the technology.

In Stage 3, given accessibility of inputs determined by the decisions in the two preceding stages, the firms choose optimal R&D effort to develop a new variety. It is assumed that the amount of R&D is translated into the variety's yield. Once the new variety is developed, it is released to heterogeneous farmers. In Stage 4, farmers make their adoption decisions and the research firms compete in prices for their varieties.

To obtain a time-consistent solution, the model is solved by backward induction.

4.3.1 Stage 4: Adoption and Pricing Decisions

In modeling farmers' choices, the approach of Malla, Gray (2005) is followed. It is assumed that farmers are differentiated according to some characteristic ϕ. Farmers decide whether

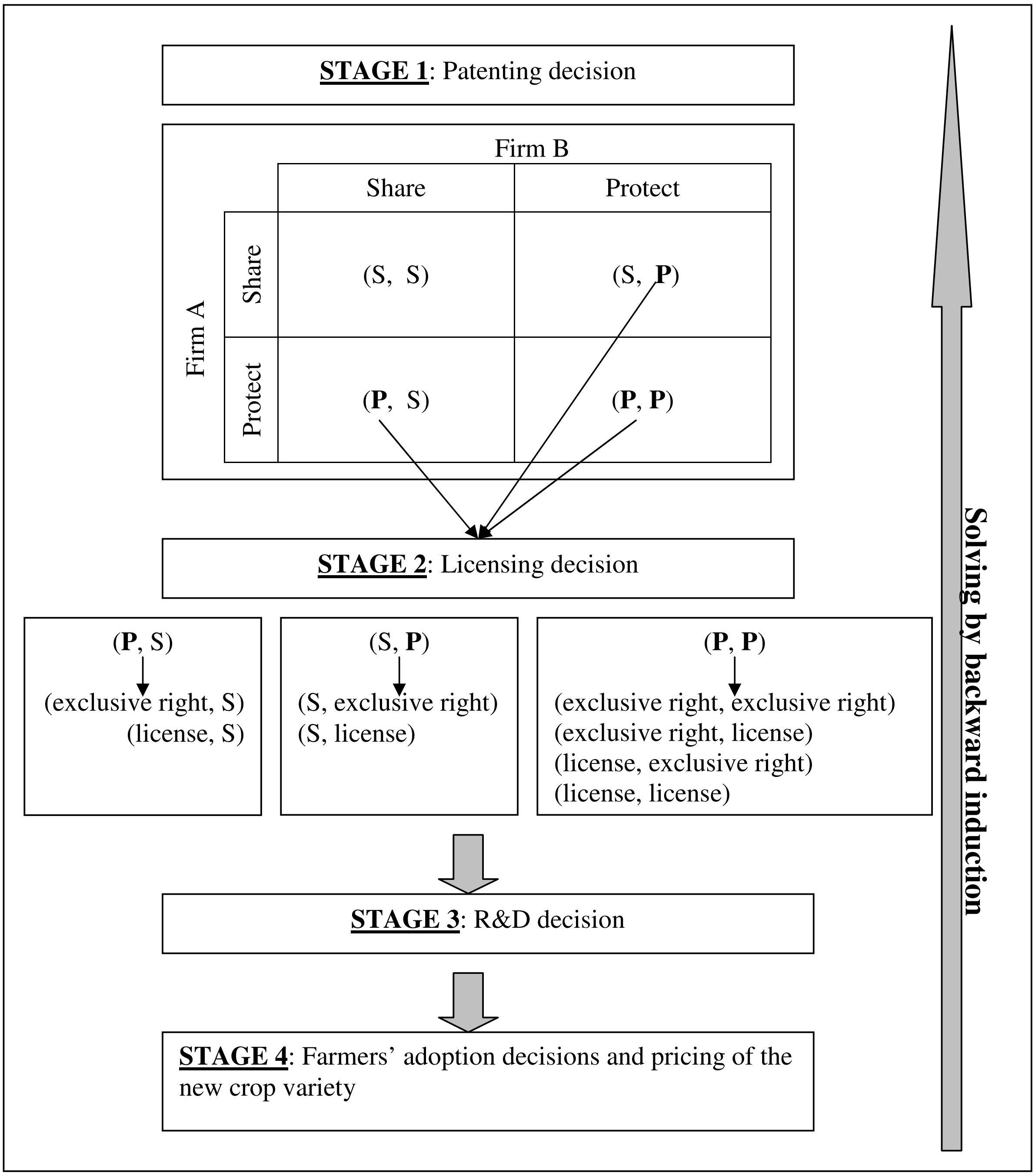


Figure 4.1: Set up of the game

to grow a particular crop, e.g., wheat, and then choose which variety to plant, A or B. The choice of farmers is represented in Figure 4.2.

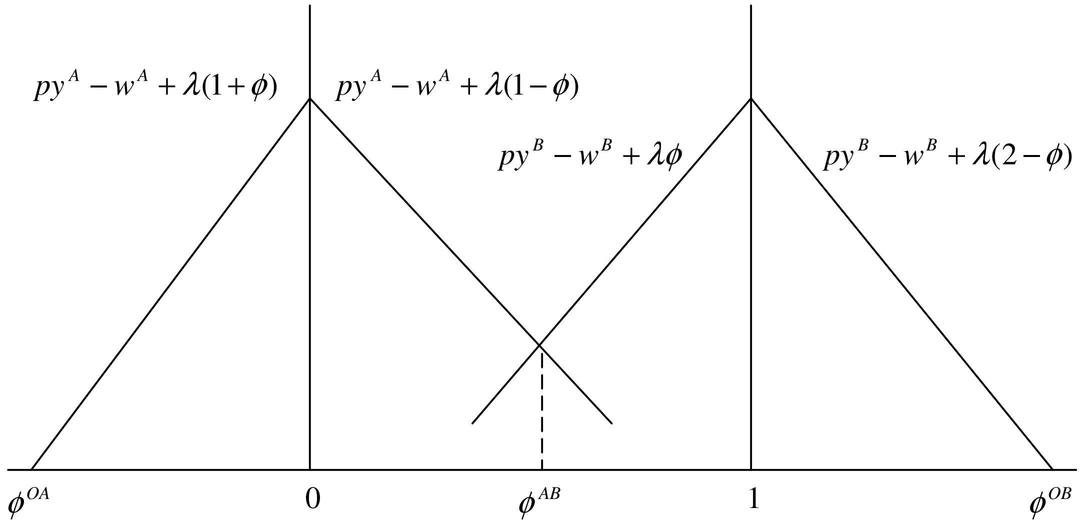


Figure 4.2: Farmers' choice of a variety

In Figure 4.2 Variety A and Variety B compete at the external margin with other crops in the $0\phi^{OA}$ and $1\phi^{OB}$ planes, respectively. In the middle, varieties compete against each other. If, for example, the yield of Variety A increases, then $py^A - w^A + \lambda(1 + \phi)$ and $py^A - w^A + \lambda(1 - \phi)$ curves shift up. As a result, Variety A will capture some market share from another crop and some market share from Variety B.

In the region $0\phi^{OA}$, the profit of a farmer who chooses Variety A of a particular crop over other crops is given by:

$$\Pi^{AO} = py^A - w^A + \lambda(1 + \phi). \tag{4.1}$$

The profit of a farmer who chooses Variety A over Variety B is:

$$\Pi^{AB} = py^A - w^A + \lambda(1 - \phi). \tag{4.2}$$

If Variety B is chosen, then the farmer's profits are:

$$\Pi^{BA} = py^B - w^B + \lambda\phi \tag{4.3}$$

in the region where it competes with Variety A, and

$$\Pi^{BO} = py^B - w^B + \lambda(2 - \phi) \tag{4.4}$$

in the region $1\phi^{OB}$ where it competes with other crops.

The model has been set up analogous to Malla, Gray (2005) such that farmers who adopt Variety A (Variety B) get a maximum of $py^A - w^A + \lambda$ ($py^B - w^B + \lambda$) at a point $\phi = 0$ ($\phi = 1$). Moving away from $\phi = 0$ ($\phi = 1$), the benefits to farmers from seeding Variety A (Variety B) decline.[1]

By equating (4.1) to zero and solving for $-\phi$ yields one portion of demand for Variety A: $-\phi = \frac{py^A+\lambda-w^A}{\lambda}$. The farmer with a differentiating characteristic ϕ^{AB} who is indifferent between planting Variety A and Variety B can be found by equating (4.2) and (4.3). $0\phi^{AB}$ will give the other portion of the demand for Variety A. Total demand for Variety A is $\phi^{OA}\phi^{AB}$ and is equal to:

$$q^A = \frac{3py^A + 3\lambda - 3w^A - py^B + w^B}{2\lambda}. \tag{4.5}$$

The demand for Variety B is $\phi^{OB} - \phi^{AB}$, where ϕ^{OB} can be found by equating (4.4) to zero. Therefore,

$$q^B = \frac{3py^B + 3\lambda - 3w^B - py^A + w^A}{2\lambda}. \tag{4.6}$$

So, as the above equations show, the amount of Variety A demanded is a function of the price for Variety B as well as a function of Variety B's yield. The demand for Variety B, in its turn, is a function of Variety A's price and yield.

There is a duopoly on the seed market and Firms A and B compete in prices. It is assumed that the marginal cost of seed production for both firms is zero. Each firm sets the price and quantity of seed sales such that profits $\Pi_i = w_i q_i(w_i)$, for $i = A, B$ are maximized. This yields the following Bertrand-Nash equilibrium in prices and quantities:

$$w^{A*} = \frac{17py^A + 21\lambda - 3py^B}{35}, and \tag{4.7}$$

[1] It should be mentioned that the model could be set up such that farmers get a maximum of $py^A - w^A$ and $py^B - w^B$ from planting Variety A and B, respectively. In this case, the profit equation in the ϕ^{OA} region, where farmers choose between wheat and other crops, would have to be defined as $py^A - w^A + \lambda\phi$, and the one in the $0\phi^{AB}$ region as $py^A - w^A - \lambda\phi$. For farmers making choice about Variety B, the profits would have to be specified as $py^B - w^B - \lambda(1 - \phi)$ and $py^B - w^B + \lambda(1 - \phi)$ in the $\phi^{AB}1$ and $1\phi^{OB}$ regions, respectively. Both specifications of the profit equations, however, would yield the same seed demand equations.

$$w^{B*} = \frac{17py^B + 21\lambda - 3py^A}{35}, and \tag{4.8}$$

$$q^{A*} = \frac{3(17py^A + 21\lambda - 3py^B)}{70\lambda}, and \tag{4.9}$$

$$q^{B*} = \frac{3(17py^B + 21\lambda - 3py^A)}{70\lambda}. \tag{4.10}$$

Profits for Firm A and B from selling the seed are given by:

$$\Pi_A^* = \frac{3(17py^A + 21\lambda - 3py^B)^2}{2450\lambda}, \tag{4.11}$$

and

$$\Pi_B^* = \frac{3(17py^B + 21\lambda - 3py^A)^2}{2450\lambda}. \tag{4.12}$$

That the two varieties are substitutes is reflected in the profit functions. An increase in Variety B's yield, for example, increases the farmers' demand for this variety, thus reducing market share and, consequently, profit for Firm A.

4.3.2 Stage 3: R&D Decision

The two life science companies perform R&D to achieve a certain yield level y^A and y^B. It is assumed that firms are symmetric and that the cost of achieving y_i is

$$C(y_i) = \frac{b(y_i)^2}{2} - I\theta y^i, \tag{4.13}$$

where I is an indication function and $I = 1$ if firms exchange their technologies/inputs and $I = 0$ if firms do not permit access to their proprietary technologies/inputs, θ is a parameter capturing the value of the other firm's technology and larger values of θ indicate more important innovations. It is assumed that there are two inputs - Firm A owns one and Firm B owns the other. Both inputs must be combined in order to produce output - a new variety. If one firm can gain permission to use the technology owned by its rival, then it will not have to bear additional costs to develop an alternative input that does not infringe on the patent. Thus, the sharing of technologies prevents duplicative R&D efforts as well as enhances the technological level of the firm due to a spillover effect, which, in turn, reduces marginal costs of research (Figure 4.3). This is captured by the last term in the specified research cost function[2].

[2]It is assumed that licensing (sharing) of technologies brings about a parallel downward shift in the marginal cost function. It has also been tested for a situation where there is a pivotal shift in the marginal cost function, and the results are essentially the same.

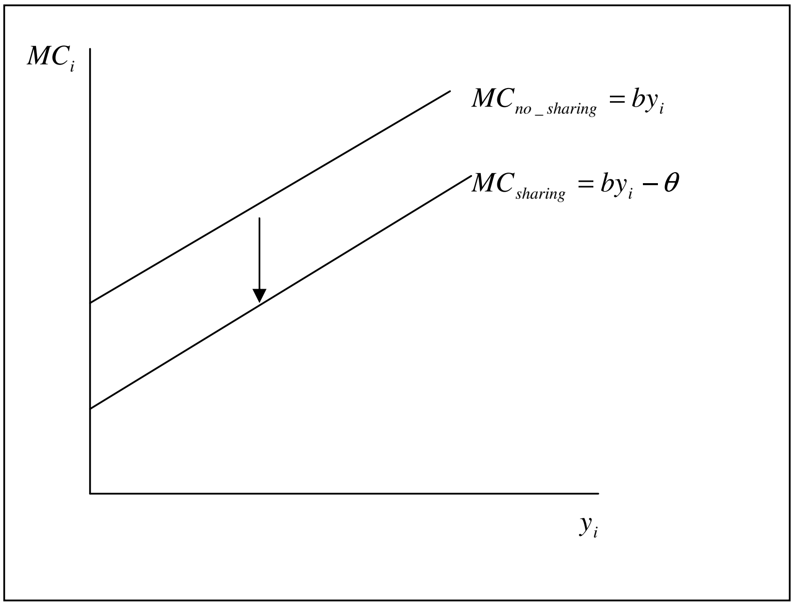


Figure 4.3: Marginal costs of research and sharing

When both firms have patents on their technologies, they have an option of licensing or restricting access. Thus, there are four possibilities open to firms: (1) cross-licensing - (l, l); (2) Firm A licenses its technology to Firm B but Firm B maintains an exclusive right over its - (l, x); (3) Firm A maintains an exclusive right while Firm B licenses - (x, l); and (4) both firms restrict access to their technologies - (x, x). It is assumed that firms are non-cooperative at the R&D stage - each firm chooses the yield level, y^i, and, consequently, the R&D effort to maximize its own profits rather than joint profit.

When firms cross-license their technologies, they choose the innovation effort such that the following profit functions are maximized:

$\Pi^A_{(l,l)} = \frac{3(17py^A+21\lambda-3py^B)^2}{2450\lambda} - \frac{b(y^A)^2}{2} + \theta y^A$; and

$\Pi^B_{(l,l)} = \frac{3(17py^B+21\lambda-3py^A)^2}{2450\lambda} - \frac{b(y^B)^2}{2} + \theta y^B$.

When Firm A licenses its technology but Firm B restricts access to its technology firms maximize:

$\Pi^A_{(l,x)} = \frac{3(17py^A+21\lambda-3py^B)^2}{2450\lambda} - \frac{b(y^A)^2}{2} + f$, where f is the fixed licensing fee, and

$\Pi^B_{(l,x)} = \frac{3(17py^B+21\lambda-3py^A)^2}{2450\lambda} - \frac{b(y^B)^2}{2} + \theta y^B - f$

When both firms block access to their technologies, gains in the form of reduced marginal costs are not realized. Thus, the firms choose their R&D effort to maximize the following profit functions:

$\Pi^A_{(x,x)} = \frac{3(17py^A+21\lambda-3py^B)^2}{2450\lambda} - \frac{b(y^A)^2}{2}$; and

$\Pi^B_{(x,x)} = \frac{3(17py^B+21\lambda-3py^A)^2}{2450\lambda} - \frac{b(y^B)^2}{2}$.

To ensure concavity of profits in y^i, the following condition must hold:

$(867p^2 - 1225\lambda b) \leq 0$.

The optimal solutions for the research effort embodied in yield levels under each scenario are presented in Table 4.1.

Table 4.1: *Optimal yield levels of the firms*

		Firm B	
		Exclusive right	*License*
Firm A	*Exclusive right*	$y^A_{(x,x)} = y^B_{(x,x)} = \frac{153\lambda p \cdot (245\lambda b - 204p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$	$y^A_{(x,l)} = \frac{\lambda(37485\lambda bp - 31212p^3)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4} - \frac{\lambda(42875\lambda b\theta - 30345\theta p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$ $y^B_{(x,l)} = \frac{153\lambda p \cdot (245\lambda b - 35\theta p - 204p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$
	License	$y^A_{(l,x)} = \frac{153\lambda p \cdot (245\lambda b - 35\theta p - 204p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$ $y^B_{(l,x)} = \frac{\lambda(37485\lambda bp - 31212p^3)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4} - \frac{\lambda(42875\lambda b\theta - 30345\theta p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$	$y^A_{(l,l)} = y^B_{(l,l)} = \frac{\lambda(175\theta + 153p)(245\lambda b - 204p^2)}{42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4}$

Proposition 4.1. *R&D effort will be the highest for a firm when it acquires access to the other firm's technology but maintains an exclusive right over its own technology.*

This result is obtained by comparing the optimal yield levels and taking into account that research expenditures of firm i, $i = (A, B)$, are increasing in the achieved yields. Comparing optimal choices and using the second order condition for profit maximization generates the following:

$$y^A_{l,x} - y^A_{l,l} = -35\lambda\theta(1225\lambda b - 867p^2) \leq 0,$$
$$y^B_{l,x} - y^B_{l,l} = 5355\lambda b p^2 \geq 0,$$
$$y^A_{l,x} - y^A_{x,x} = -5355\lambda b p^2 \leq 0,$$
$$y^B_{l,x} - y^B_{x,x} = 35\lambda\theta(1225\lambda b - 867p^2) \geq 0,$$
$$y^B_{l,l} - y^B_{x,x} = y^A_{l,l} - y^A_{x,x} = 175\lambda\theta(245\lambda b - 204p^2) \geq 0.$$

The above inequalities indicate that if one firm defects and makes its inputs private, then the other firm cuts down on R&D. Both firms invest in research more when they cooperate in terms of access to research inputs.

4.3.3 Stage 2: Licensing Decision

When firms make patenting and licensing decisions, they move sequentially, as shown in Figure 4.4. First, Firm A decides whether to patent its technology or place it in the public domain. Based on the choice of Firm A, Firm B decides whether to protect its technology or make the technology public. If both firms apply patents, then at the next stage they simultaneously make decisions whether to license the technology to the other firm, cross-license, or maintain an exclusive right over the technology. Despite Firm A having a patent on its technology, if Firm B decides to make the technology public - i.e., freely share its technology - then Firm A decides whether to license the technology to Firm B. If Firm A initially chooses to make its technology publicly available, Firm B decides whether to follow suit, in which case research inputs are freely shared, or to protect its technology and either license it or maintain exclusive rights.

To find a sub-game perfect Nash equilibrium of this part of the game, the next step is to compute the backward-induction outcome. This begins at the last stage, when firms simultaneously decide whether to license the technologies, given that both firms have applied patents.

If firms share their technologies, there are two effects. One is on the cost side. Obtaining the technology saves on R&D costs, which is beneficial for both firms. If, however, final products are substitutes, then sharing the technology enhances competition on the final good market, which negatively affects profits.

Firms' profits are presented in Table 4.2. Comparing the profits under (l, l) and (x, x)

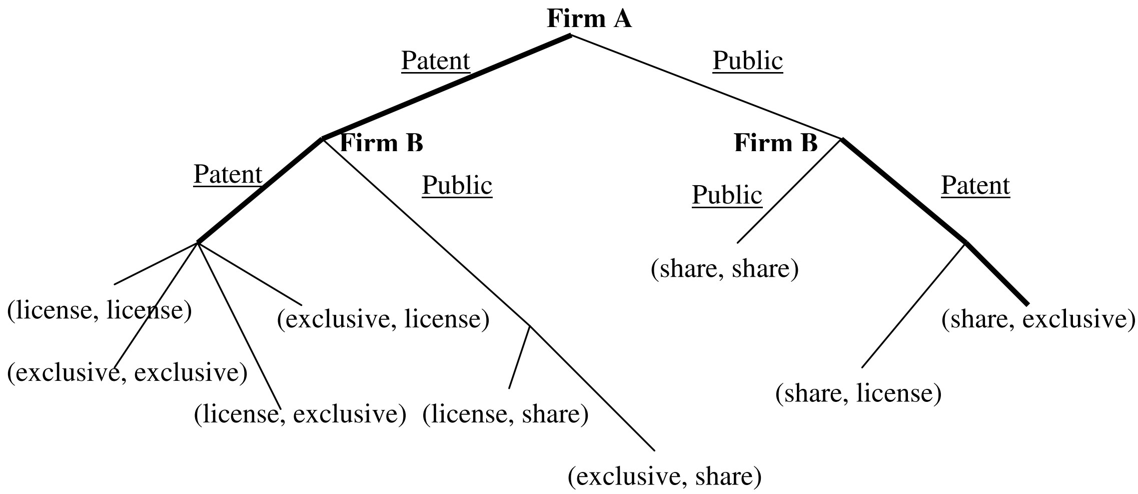


Figure 4.4: Dynamic game of patenting

scenarios, and using the second order condition for profit maximization gives:

$$\Pi_{(l,l)} - \Pi_{(x,x)} = \frac{\lambda\theta(245\lambda b - 204p^2)^2(875\theta(35\lambda b - 24p^2) + 36p(1225\lambda b - 867p^2))}{2A^2} \geq 0,$$

where $A = 42875\lambda^2 b^2 - 60690\lambda b p^2 + 20808 p^4$. This result gives rise to the following proposition:

Proposition 4.2. *When two firms compete in the differentiated product market they are both better off cross-licensing their technologies rather than enclosing their knowledge.*

The pay-offs to firms when one licenses the technology and the other makes the technology private depend on the licensing fee. In a case of low licensing fee, firms' pay-offs will follow the same pattern as R&D investments. Specifically, if

$$f \leq \frac{945\lambda^2 b\theta p(1225\lambda b - 867p^2)(490\lambda b - 35\theta p - 408p^2)}{2A^2} \tag{4.14}$$

then the pay-off to Firm A in (license, exclusive) case, $\Pi^A_{(l,x)}$, is smaller than under (exclusive, exclusive), $\Pi^A_{(x,x)}$. This condition also ensures that $\Pi^B_{(l,x)} \geq \Pi^B_{(l,l)}$[3]. $\Pi_{(l,l)} \geq \Pi_{(x,x)}$ implies that when Firm B defects, Firm A gets the least preferred pay-off, while defection yields the first best outcome for Firm B.

[3]Firm B will gain from defection if the licensing fee it has to pay to Firm A is small: $f_B \leq \frac{315\lambda\theta p(1225ab - 867p^2)(6\lambda b(245\lambda b - 204p^2) + \theta p(1085ab - 816p^2))}{2A^2}$. This license fee guarantees a positive pay-off to Firm B: $\Pi^B_{(l,x)} = \frac{\lambda(245\lambda b - 204p^2)^2(36\theta p(1225\lambda b - 867p^2) + 27\lambda b(1225\lambda b - 867p^2) + 25\theta^2(1225\lambda b - 840p^2))}{2A^2} \geq 0$. Furthermore, f_B is higher than the licensing fee specified in (4.14). Therefore, condition (4.14) also implies that $\Pi^B_{(l,x)} \geq \Pi^B_{(l,l)}$

Table 4.2: *Firms' profits under different research interactions*

		Firm B	
		Exclusive right	*License*
Firm A	*Exclusive right*	$\Pi^A_{(x,x)} = \Pi^B_{(x,x)} = = \dfrac{27\lambda^2 b(1225\lambda b - 867p^2)(245\lambda b - 204p^2)^2}{2(42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4)^2}$	$\Pi^A_{(x,l)} = \dfrac{K_2}{2A^2} - f$ $\Pi^B_{(x,l)} = \dfrac{27\lambda^2 b(1225\lambda b - 867p^2)}{2A^2} \times \times \dfrac{(245\lambda b - 35\theta p - 204p^2)^2}{2A^2} + f$
	License	$\Pi^A_{(l,x)} = \dfrac{27\lambda^2 b(1225\lambda b - 867p^2)}{2A^2} \times \times \dfrac{(245\lambda b - 35\theta p - 204p^2)^2}{2A^2} + f$ $\Pi^B_{(l,x)} = \dfrac{K_2}{2A^2} - f$	$\Pi^A_{(l,l)} = \Pi^B_{(l,l)} = = \dfrac{\lambda(245\lambda b - 204p^2)^2 K_1}{2(42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4)^2}$

where

$A = 42875\lambda^2 b^2 - 60690\lambda bp^2 + 20808p^4$

$K_1 = 44100\lambda b\theta p + 33075\lambda^2 b^2 + 30625\lambda b\theta^2 - 31212\theta p^3 - 21000\theta^2 p^2 - 23409\lambda bp^2$

$K_2 = -12989185592\theta p^7 - 6510823320\theta^2 p^6 - 974188944\lambda bp^6 + 5289497640\lambda b\theta p^5 + 3716412840\lambda^2 b^2 p^4$
$+ 2762457075\lambda b\theta^2 p^4 - 7155511650\lambda^2 b^2\theta p^3 - 4711302225\lambda^3 b^3 p^2 - 3903125625\lambda^2 b^2\theta^2 p^2 +$
$+ 3214338750\lambda^3 b^3\theta p + 1985326875\lambda^4 b^4 + 1838265625\lambda^3 b^3 c^2$

To find a Nash equilibrium of the game when condition (4.14) holds, arbitrary numbers are used such that follow the inequalities in the above equations. An example of firms' pay-offs is given in Table 4.3.

As can be seen from Table 4.3 for both firms "exclusive right" dominates "licensing". If firms are rational, they will always choose to restrict access to their technology, no matter what the rivals are doing. Thus, even though cross-licensing is mutually beneficial for firms, the outcome when both maintain exclusive rights over their technologies is a Nash equilibrium. This is a typical representation of the "prisoner's dilemma."

Proposition 4.3. *When two firms compete in the differentiated product market and the symmetric licensing fee is below a specific threshold (as defined by (4.14)), both firms will have an incentive to enclose their technology, leading to a tragedy of the anticommons.*

This result helps to explain why a tragedy of anticommons may arise. In a world where

Table 4.3: *An example of a pay-off in the presence of private gains from unilateral technology enclosure*

		Firm B	
		Exclusive right	*License*
Firm A	*Exclusive right*	(2.5, 2.5)[1]	(3.5, 2)
	License	(2, 3.5)	(3, 3)

[1] – The first number in the parenthesis indicates a pay-off to firm A; the second number – the pay-off to Firm B

Source: Author (see text)

every player protects intellectual property, companies will insist on making the technology unavailable to competitors. Because R&D expenditures follow the same pattern as pay-offs, the Nash equilibrium outcome implies that the result of knowledge/research input enclosure is a reduction in downstream research. Equivalent to the (exclusive, exclusive) outcome would be an environment where firms choose to keep information secret. This would be the choice when patenting costs are high relative to the extra security costs that firms incur to ensure that the secret is not leak. Hybrid technologies are a good example of where the parental lines are protected by trade secrets.

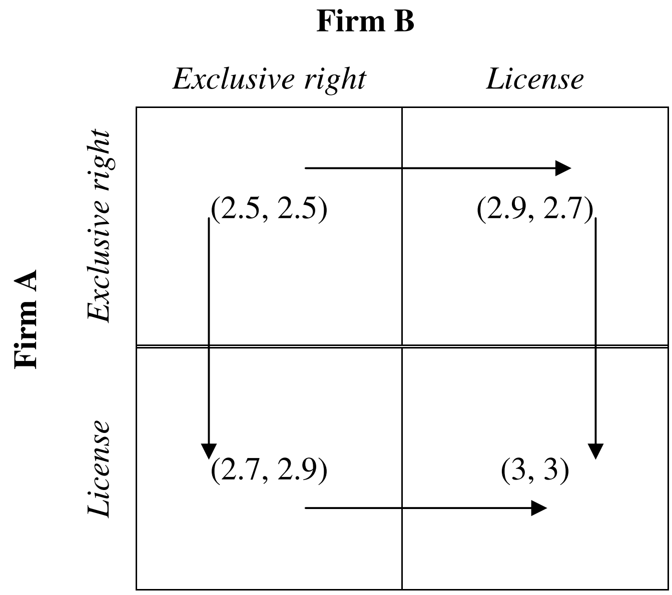
Mutual cooperation, or cross-licensing, is beneficial to both firms and society with regards to incentives for conducting research. But how can it be sustained? A famous solution is the "tit-for-tat" strategy, where "exclusive" strategy by one player is accompanied by noncooperative behaviour from the other player in the future. This strategy is applicable to situations where players repeatedly interact with each other. Knowing that not sharing will have like consequences in the future encourages players to provide access to their technologies and sustain a cooperative equilibrium. This strategy is especially important in plant breeding, where a firm cannot be self-sufficient in research inputs and must trade with others to survive. It has been employed by the breeding community: "There has always been a non-written law among breeders that if somebody will trade fairly with you, you will trade with them. If they don't trade with you, you will not trade with them."[4]

Another case where cooperative equilibrium can be sustained is when the licensing fee paid by the firm that encloses its technology is high. In this case, the gains from being a sole defector are eliminated. Specifically, if

$$f > \frac{315\lambda\theta p(1225\lambda b - 867p^2)(6\lambda b(245\lambda b - 204p^2) + \theta p(1085\lambda b - 816p^2))}{2A^2}, \tag{4.15}$$

where A is as defined above, and the fee is such that $\Pi^B_{(l,x)} \geq 0$, then $\Pi^B_{(l,x)} \leq \Pi^B_{(l,l)}$ and $\Pi^A_{(l,x)} \leq \Pi^A_{(l,l)}$, and the ranking of the pay-offs would be as in Table 4.4.

Table 4.4: *An example of firms' pay-offs when the licensing fee is high and the private gains from knowledge enclosure are eliminated*



Source: Author (see text)

In this case, the gains from enclosing the knowledge are eliminated as the firm is forced to pay a high price to access the other firm's inputs. It can easily be verified that the Nash equilibrium of this game is the (license, license) outcome.

[4]Communication with a canola breeder: Transcript C7 (Oikonomou (2007)).

Proposition 4.4. *When two firms compete in the differentiated product market and the symmetric licensing fee is above a specific threshold (as defined in (4.15)), a cross-licensing equilibrium will be sustained and the social optimum will be achieved.*

Thus, with two players a tragedy of anticommons can be avoided if the defector gets penalized for making his technology private by being excluded from using the knowledge of others in the future or by being charged a high fee to access someone else's technology.

The solution to the prisoner's dilemma is not that simple, however, if the game is generalized to n players. In the n-player game, it becomes more difficult to infer who defected (O'Riordan et al (2006)). Even if the defector is detected, reciprocity is less advantageous because by punishing the defector those who cooperated are punished (Lindgren and Johansson (1998)). Difficulties in implementing a tit-for-tat strategy in the iterated n-player game make it harder to sustain a cooperative equilibrium in the long run. Therefore, with $n > 2$ players a tragedy of the anticommons is more likely to occur. The likelihood that at least one proprietary input required for research process will be unaccessible increases with the number of players as the probability of detecting and punishing the defector falls.

4.3.4 Stage 1: Patenting Decision

Is there an incentive for firms to stay away from IP protection and freely share their technologies despite the possibility of patents? To answer this question, it is necessary to analyze other branches in Figure 4.4. If Firm A goes public (freely shares its technology), then Firm B can either follow suit or protect its technology. Profits of the two firms when firm A shares and firm B maintains an exclusive right over its technology are given by

$$\Pi^B = r^B - \frac{by_B^2}{2} + \theta y_B, \tag{4.16}$$

and

$$\Pi^A = r^A - \frac{by_A^2}{2} \tag{4.17}$$

where r^i is revenue earned on the seed market by firm $i = A, B$.

The solution is the same as in the (license, exclusive) case, with Firm A receiving no royalty for access to its technology and Firm B paying no fee. The (share, license) outcome for Firm B will be identical to the (license, license) outcome plus the licensing fee paid by

Firm A. And (share, share) outcome is the same as in the cross-licensing case. Thus, given that Firm A freely disseminates the technology the possible rewards to Firm B are represented in Figure 4.5.

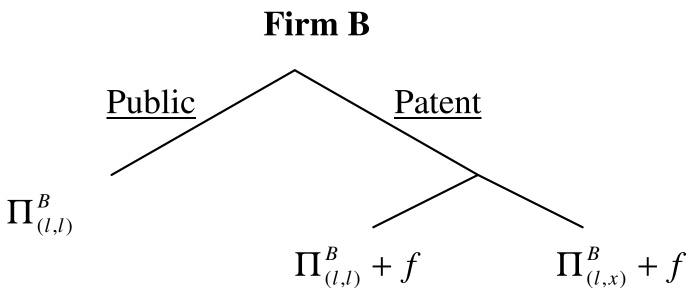


Figure 4.5: Firm B's pay-off given that Firm A goes public

If the costs of patenting are smaller than the licensing fee, it is obvious that Firm B gains by protecting its IP because it allows the extraction of a royalty from Firm A while using Firm A's technology for free. Thus, when one firm places the technology in the public domain, the other will have an incentive to protect its own rather than freely share. Furthermore, if the licensing fee $f \leq \frac{945\lambda^2 b\theta p(1225\lambda b - 867p^2)(490\lambda b - 35\theta p - 408p^2)}{2A^2}$ then $\Pi^B_{(l,x)} > \Pi^B_{(l,l)}$, and Firm B will have an incentive to keep its technology private. Given the specified royalty structure in equilibrium, Firm B will protect its technology and maintain an exclusive right.

If Firm A applies a patent but Firm B decides to disclose its technology, then the pay-offs to Firm A will follow the pattern illustrated in Figure 4.6.

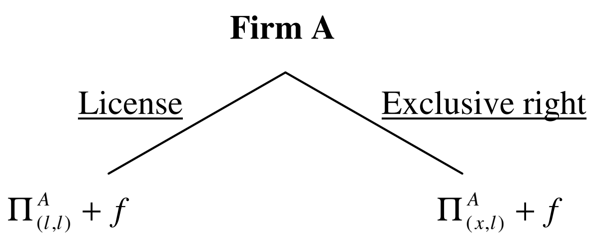


Figure 4.6: Firm A's pay-off given that Firm A patents and Firm B goes public

If the licensing fee is $f \leq \frac{315\lambda\theta p(1225\lambda b - 867p^2)[6\lambda b(245\lambda b - 204p^2) + \theta p(1085\lambda b - 816p^2)]}{2A^2}$, then Firm A will choose to enclose its knowledge.

If the fee to access the technology is as defined in (4.14) then the sub-game perfect Nash equilibria are as presented in Figure 4.7.

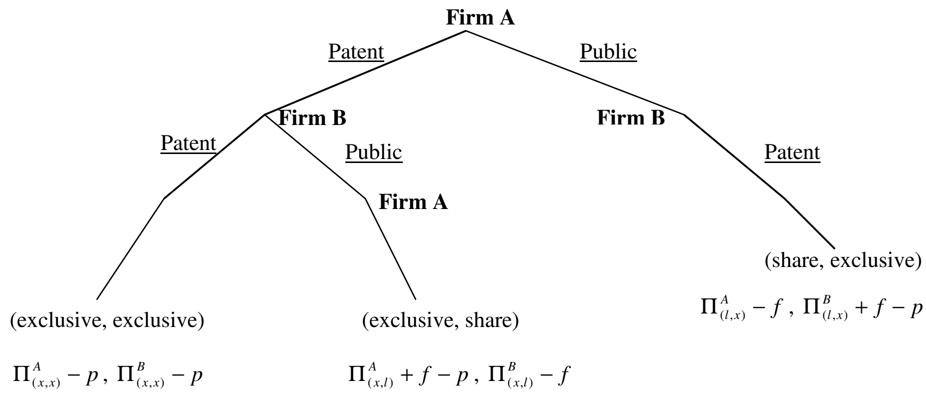


Figure 4.7: Subgame perfect Nash equilibria for the patent game

If the licensing fee exceeds the cost of patenting, then Firm B, knowing that Firm A will maintain an exclusive right over its knowledge if Firm B places its knowledge in the public domain, will be better off by applying a patent and playing (exclusive, exclusive). Firm A, in its turn, will not go the "public route" either because it knows that in this case Firm B will enclose its technology, which will yield a lower pay-off to Firm A than under (exclusive, exclusive) outcome. Thus,

Proposition 4.5. *When firms anticipate an enclosure equilibrium under IP protection they will have an incentive to protect their IP if IP protection costs are lower than the symmetric licensing fee.*

When the equilibrium of the patent game is cross-licensing, then $\Pi^A_{(l,x)} \leq \Pi^A_{(l,l)}$ and $\Pi^B_{(x,l)} \leq \Pi^B_{(l,l)}$. Therefore, given that IP protection costs are lower than the licensing fee protecting and cross-licensing technology will be beneficial for each firm compared to free sharing outcome. This gives rise to the following proposition:

Proposition 4.6. *When firms anticipate a cross-licensing equilibrium under IP protection they will have an incentive to protect their IP if IP protection costs are lower than the symmetric licensing fee.*

Combining the two last propositions yields the following:

Proposition 4.7. *If IP protection costs are lower than the licensing fee, in equilibrium firms move away from the free sharing of knowledge/technologies toward IP protection.*

A very recent phenomenon in the plant research industry that deserves investigation is the emergence of sharing agreements in the biotech industry. Monsanto and Bayer have been developing their own technologies for about twenty years blocking access to each other's IP pools (Smyth (2008)). Recently, they shifted to cross-licensing strategy. An interesting question is "Why did they not share their technologies for such a long time?" A number of explanations can be forward. First, it is possible that the companies have been able to play long enough to figure out the cooperation strategy. Second, the companies may have reached the point where the costs of having the two IP pools split have become prohibitely costly. The model outlined in this section suggests that cooperation can be sustained when firms have to pay high costs to get technologies owned by others. In other words, when this happens it is better to cooperate than pay these high costs. These costs should not only include direct resources paid to obtain access to research tools, they can also be the costs associated with not being able to do certain lines of research due to lack of IPs. Third, these companies have kept their technologies proprietary for rather a long time and at this stage patents may be expiring. Fourth, the companies may be heading towards creating a monopoly.

4.4 Conclusions

IP protection of upstream innovations can provide stronger incentives to engage in research, but it can also interfere with the ability of scientists to conduct downstream research as access to research inputs becomes restricted. Theoretical and empirical studies presented in this chapter suggest that in industries where innovations are cumulative, IPRs are not beneficial to R&D. On the contrary, they block access to technologies and raise the costs of follow-on research, thus reducing R&D effort.

Pointing to the historical evidence where IPRs were non-existent in the Canadian plant breeding industry, the system where major technologies were freely shared among scientists proved to be highly beneficial for both researchers and society as a whole. If everybody gains from sharing their technologies, why are there apprehensions that IPRs may bring the culture of sharing to extinction? If sharing were beneficial, then one would expect firms to use proprietary inputs to enter license agreements, thereby increasing revenues, rather than keep the technologies exclusively for private use.

In this chapter, a theoretical model has been developed to look into the incentives of firms to share their technologies with competing firms in a world of IP protection. It is assumed that access to technologies owned by others allows a firm to avoid costly duplicative effort, thus reducing the costs of developing a product. Because firms compete in the final product market, providing technology to a rival reduces a firm's market share and revenues. Because of these effects, then, each firm would benefit from access to the rival's technology and enclosure of its own technology.

The results of the theoretical model suggest that no protection and a free sharing of technologies is the best outcome in terms of R&D rewards and efforts. It is, however, not sustainable because each firm can benefit from unilateral IP protection. Therefore, if patenting is possible, in the equilibrium firms will move away from free sharing to IP protection.

When technologies are protected by patents, cross-licensing of technologies yields the highest payoffs for both firms and ensures the highest R&D effort. However, it is not necessarily the equilibrium outcome of the game. If the cost of accessing the other firm's technology is relatively low, then licensing for each firm will be dominated by an exclusive right over the technology. This will lead to an equilibrium where each firm keeps exclusive rights over their technologies, even though the firms could gain from a mutual cooperation.

Cooperation (technology sharing) can be sustained if the firms have to pay a high price to access the other firm's technology, so that the gains from unilateral defection are eliminated. In a case of two firms, this equilibrium can be sustained if the tit-for-tat strategy is employed and the cooperating firm penalizes the defector by denying access to its technology in the future. Things are more complicated, however, when multiple owners of IP are involved. The larger the number of firms, the lower the probability of detecting the defector and the higher the probability that at least one of the firms will deny access to its technology, thus making a tragedy of anticommons more likely.

To summarize, the results suggest that sharing within private industry may be a challenge.

Enclosure of technologies by private firms is unlikely to leave the public sector unaffected. If public researchers do not protect their technologies while private firms do, then they will find themselves in the worst situation, one where they will be locked out of the market. Protection of technologies by public institutions is important to conduct research as it gives something to trade with the private industry, thus opening access to private technologies. Therefore, a propensity to protect technologies by private firms will undoubtedly translate into increased protection by public institutions. The next chapter looks at how IPRs have affected public institutions in the wheat and canola breeding sectors in Canada.

Chapter 5

IPRs, THE TRAGEDY OF ANTICOMMONS, AND FREEDOM TO OPERATE ISSUES: A CASE STUDY OF THE WHEAT AND CANOLA BREEDING INDUSTRIES

5.1 Introduction

As intellectual property rights (IPRs) proliferate, the Canadian crop research industry is facing new constraints and questions. Through the use of biotechnologies, the plant breeding process has become faster but also more complex, relying extensively on previous advances in the sector and requiring access to many pieces of intellectual property (IP). Theoretical and empirical literature reviewed in Chapter 4 suggests that protection of upstream innovations can pose serious threats to further research. As long as access to existing technologies makes research more productive, sharing or cross-licensing of technologies contributes to achieving a social optimum in R&D. Within the private industry, however, there is lack of incentive to share/cross-license research inputs. A propensity to patent and withhold research inputs may not, however, be confined to private firms. Application of IPRs by private firms may encourage public researchers to enclose their knowledge in order to use it as a bargaining chip with others. Therefore, an interesting economic question to look into is whether IPRs have affected the willingness of public researchers to share research materials and ideas.

The impact of protecting research inputs on the ability and incentives of public institutions to conduct research is not well understood. A general perception is that IPRs are important where the private sector is concerned, but they are not driving public research and IPRs are not important for the public sector because public researchers serve the interests of the wider society. However, there is evidence that the public sector has become overwhelmed in the process and is moving aggressively toward patenting. A fine example is a recent American patent on a new canola variety developed by Agriculture and Agri-Food Canada (AAFC) in collaboration with the Saskatchewan Wheat Pool, and filed by the AAFC (Kuyek (2004), p. 23).

According to the growing literature, IPRs can impede public research or change its nature in a number of ways. First, the prospect of financial gains may increase the unwillingness of researchers to share information and research materials with one another. Sharing may become extremely limited at early stages of the research process before patents are secured, thereby delaying breakthroughs in the industry and impeding the realization of research efficiencies and complementarities (Walsch et al (2005)). Second, because most IP in biotechnology is concentrated in the hands of the private sector, public researchers are encouraged to form close ties with the industry to ensure access to basic technologies and freedom to operate. Collaborative agreements with the industry may predetermine the choice of research projects and divert research effort away from basic research toward commercial "near market" research, thus jeopardizing sustainable long-term development in the breeding industry (Acker (2005)). Third, access restrictions on enabling technologies can increase the cost of conducting research in public institutions. In some cases, accessing all pieces of IP may become prohibitively costly, thereby shutting out public researchers from potentially promising areas of research.

As researchers encounter difficulties in accessing proprietary research inputs, and are forced to look for new approaches to conduct research, the effectiveness of IPRs as a mechanism to foster innovations is being questioned and a careful assessment of the performance of the IP protection system is needed.

The purpose of this chapter is to evaluate the efficiency of the current plant IP protection system in the Canadian breeding industry. The results of interviews with canola and wheat breeders are used to examine changes in the application of IPRs in plant breeding and the effect of changing IP environment on research programs, the willingness of researchers to share knowledge/research materials, and the abilities of researchers to access proprietary research materials and conduct downstream research.

The choice of the canola and wheat sectors for this study was not arbitrary. These crops have followed divergent paths since the early 1990s. Prior to 1985, breeding in the canola industry was performed primarily by the public sector, with private investment accounting for no more than two percent. After 1985, however, the canola sector underwent significant transformations, and by 2000 the private sector accounted for over 85% of total expenditure on canola research (Kuyek (2004)). Expansion of the private sector in this field has led to more property rights assigned to research tools, leaving only a limited number of technologies (genomic information, public germplasm, and traditional breeding technologies) in the public domain (Phillips (2000)).

In contrast to the canola sector, the application of biotechnology in the wheat sector has been rather limited up until recently. Wheat breeding research worldwide, and in Canada in particular, has traditionally been performed primarily in public institutions. On the global level, however, the private sector is starting to show increased interest in wheat, with biotechnology devices and IPRs finding greater applications in wheat breeding (Jordan (2000)). In the near future, we are likely to witness greater involvement of the private sector and increasing application of IPRs in wheat, and it is likely that developments in the wheat sector will resemble those in the canola industry. Therefore, evaluating the efficiency of the current IP protection system in wheat breeding, and complementing the picture with evidence from the canola sector, will provide the basis for a discussion of future prospects for the wheat breeding industry and the role of public sector in biotech research.

This chapter is structured as follows. Section 5.2 reviews changes in research environment in the wheat and canola breeding sectors since the biotechnology era. Section 5.3 presents the results of a survey of plant breeders and addresses the following issues: willingness of researchers to share ideas/research materials; access to proprietary inputs; IPRs and delays in research; impact of public-private collaboration on IP policy and dissemination of knowledge; freedom to operate (FTO); and working solutions to FTO. The analysis is concluded in Section 5.4.

5.2 IPRs and the Plant Breeding Industry

In the early 1980s, the public sector still accounted for 100% of formal plant breeding for cereals and oilseeds (GRAIN (2003b)). Introduction of IPRs in the form of Plant Breeder's Rights in 1990 and the permission to patent the within-cell processes seem to have changed the structure of research industries by attracting more private investment and crowding out the public sector. By 1997, public agricultural research spending dropped to $374 mln. from $419 mln. in 1990, while private investment expanded by 38% in real terms (Stovin and Phillips (2005)). However, developments in the breeding sectors have not been the same across different crops, with the majority of private investment targeted on a narrow range of industrial crops that could be protected by patents. Because the primary interest here is on the canola and wheat sectors, this section discusses how the two breeding sectors have changed since the advent of IPRs.

Wheat Sector

The complexity of the wheat genom and difficulties in hybridizing and applying DNA modification techniques, combined with global consumer resistance towards genetically engineered wheat, have made this crop unattractive to the private sector. The wheat breeding sector has not really changed over the last several decades, where the public sector still plays the dominant role in research. A look at the list of recommended varieties for Saskatchewan shows that a vast majority of varieties of all types of wheat have come, and still come, from public breeding programs (Varieties of Grain Crops, Saskatchewan Agriculture and Food).

Because of the limited use of molecular modification techniques and preponderance of the public sector, patents have not gained prominence in the wheat research industry. Patents are applied to enabling technologies that accelerate conventional breeding, such as DNA markers and mapping technologies, while developed varieties are protected by plant breeders' rights (PBRs). The breeders' exemption clause is to ensure that germplasm is available to breeders once the variety is released.

Canola Sector

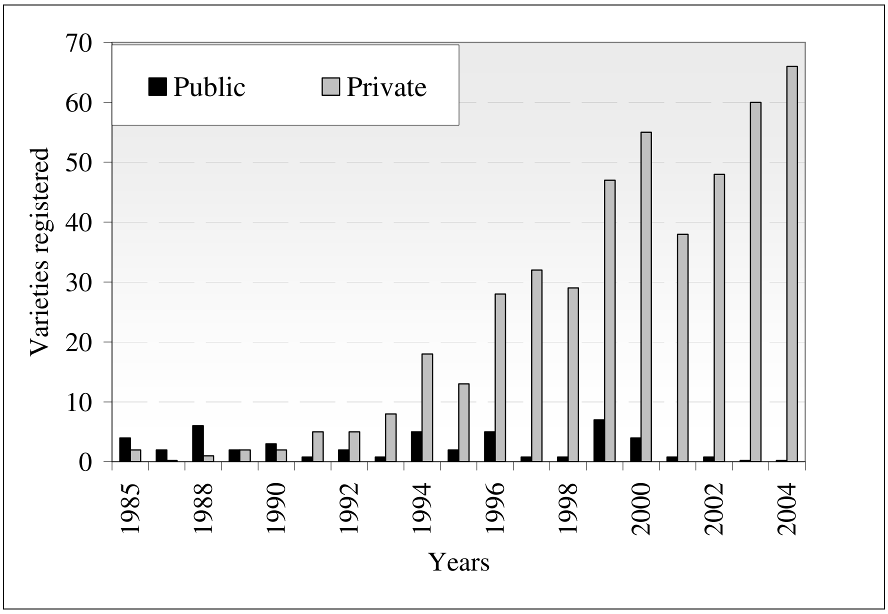
Developments in the canola sector can be divided into two periods: the pre-biotechnology era (before 1985); and the biotechnology era afterwards (Gray, Malla, and Phillips (2006)). In the pre-biotechnology era, the goal of researchers was to convert rapeseed into a competitive, edible oil. Without a proper IP protection system, the returns to canola research could not be captured by a research effort, and the market failed to attract private investment in the canola industry. During this period, virtually no private research in technology or product development was undertaken. Research funds were coming from two sources, the Rapeseed

Association, which had a self-imposed levy for research, and the Canadian government. The public sector in Canada was one of the few institutions willing to fund rapeseed research - it contributed approximately fifty percent of the total global research investment during this period (Gray, Malla, and Phillips (2006)).

By 1985, five canola varieties were registered and the "canola" trademark received (Gray, Malla and Phillips (2006)). Prior to 1985, the rate of varietal development was rather slow, with only one variety released about every two years. Plant breeding programs used non-proprietary technologies and all seeds produced and sold were in the public domain (Phillips (2000)).

Since the mid-1980s, private firms have dominated the canola research industry. Even though AAFC researchers were active in developing research tools and germplasm used by the private industry, the importance of public institutions in variety development shrank. A number of factors contributed to the influx of private investment in the canola industry by the mid-1980s. First, health research expanded the market for canola. Second, the use of genetic engineering techniques brought about faster and cheaper ways of developing varieties that, along with the introduction of intellectual property rights, attracted private sector by allowing better recouping of R&D expenditures. In 2000, private investment in the canola industry accounted for $Cnd 22.5 million (1989 dollars), which was a three-fold increase from an average of $Cnd 7.1 million per year throughout 1988-1990 (Thomas (2005)). Due to an increased involvement of the private sector, the canola industry experienced rapid expansion. Between 1982 and 1997, more than 125 varieties were introduced, with more than 75% of the new varieties developed by the private sector (Phillips (2000)). In order to facilitate market access of private sector varieties, in 1986 the Variety Registration Office agreed to support the registration of canola varieties that were *equal* or superior in performance to the reference varieties. This had a big influence on the canola industry (Carew (2000)). Figure 5.1 shows the number of varieties developed by the public and private sector that were recommended for registration during 1985-2004.

Table 5.1 presents the distribution of research results between the public and private sector in the canola industry. There was a noticeable shift from public to private investment, with the private industry contributing only 5% to research output prior to 1985, but 90% in



Source: Thomas (2005)

Figure 5.1: Public and private recommended varieties by year

the post-1985 period. Breeding efforts in the public sector declined from 20.53 professional person years (PPY) and 24.35 technical person years (TPY) in 1986 to 7.98 PPY and 7.8 TPY in 1998 (Carew (2000)).

Table 5.1: *The distribution of the canola research results between the public and private sectors*

	Share of research results, prior to 1985		Share of research results, 1986-2001	
	% new technologies	% new varieties	% new technologies	% new varieties
Government and Universities	95	95	10	14
Private companies	5	4	90	86

Source: Malla, Gray and Phillips (2006)

Profit-oriented private sector involvement significantly changed the structure of the canola breeding industry. As Table 5.2 indicates, most newly developed technologies became proprietary and cannot be freely accessed. Using proprietary material in developing new varieties without royalty arrangements negotiated before investment costs were sunk created a potential for hold-up. Furthermore, the development of new varieties that incorporated specific herbicide-tolerant traits required the cooperation of the breeding industry with the herbicide production industry. One of the solutions to the hold-up problem was the entry of large multinational research companies that kept most of the patented technologies in their domain and vertically integrated with the chemical companies (Gray, Malla, and Phillips (2006)).

Table 5.2: *IPRs in the canola breeding industry*

	Key technologies	IPR regime
Genomic information	Arabidopsis genome project, amplified fragment linkage polymorphing for gene mapping (AFLP), molecular markers	Data is in public domain but AFLP technology is patented
Germplasm	Gene banks	Access restricted for private collections
rDNA strands/genes	HT genes, antifungal proteins, antishatter, fatty acids, pharmaceutical compounds	100% private patents
General transformation technologies (general)	Agrobacterium, whiskers, biolistics, chemical mutagenesis	100% private patents except mutagenesis
Specific transformation technologies	Agrobacterium methods for brassica	100% private patents
Selectable markers	Markers for selecting specific transformants	100% private patents
Growth promoters	Constitutive and tissue specific promoters	100% private and public patents
Hybrid technologies	In-Vigor™, CMS system, Ogura CMS systems, Lemke, Kosena system, Polima	All patented except for Polima
Oil processing technologies	Oleosin partitioning technology for separating and purifying recombinant nutraceutical or pharmaceutical proteins	100% patents or trade secrets
Traditional breeding technologies	Double haploid process, backcrossing, gas liquid specrometre analysis	All in public domain

Source: Phillips (2000)

The presence of private firms in the canola research industry has not only impacted the amount of public funds available for research, but has also changed the nature of *public* canola breeding programs. Some observers have argued that public breeding programs in the canola industry have served the needs of the private sector (Carew (2000)). With increased collaboration between public and private industry, a result of the Matching Investment Initiative that was initiated by the AAFC in 1995, public research has been redirected to more applied “near market” research that is of interest to the private industry, while putting aside basic science questions regarded as detrimental to the long-term development of the industry (Acker (2005)). Matching public funds with industry money has undermined the purpose, effectiveness, and value of public research because it leads to a convergence of the public and private goals with regards to profit and IP protection (Acker (2005)). An illustrative example of this is an American patent on a new canola variety developed by the AAFC scientists in collaboration with the Saskatchewan Wheat Pool. As a Saskatchewan Wheat Pool canola breeder stressed, the AAFC insisted on applying for a patent: "They were more interested in the potential profit than we were" (Kuyek (2004), p. 23).

There are also concerns that the shift from public to predominantly private canola breeding has created controversy in the sector. Even though the Canadian Patent Act allows the use of patented material for experimental purposes, patenting can potentially change the behaviour of public breeders and further reduce incentives for the public sector to undertake research in the canola industry. First, some have noted that curtailed government funds and increased transaction costs associated with negotiating the terms of IP has forced public institutions to seek protection for their own inventions so as to recoup at least some portion of their R&D expenditures. In order to commercialize a new variety, a legal access is required for all pieces of IP used in the production process. Difficulties in obtaining the necessary permissions and licenses to use IP may discourage public sector involvement in certain areas of research. Second, acquiring protection for public sector inventions can become increasingly important when needing something to trade with private companies. This will undoubtedly reduce the amount of information and knowledge available for public use.

Empirical evidence from the pharmaceutical industry suggests that the prospect of future gains from R&D tends to make researchers more reluctant to share research results with others, at least before their innovations find commercial applications and patents are obtained. Thus, the controversy of IPRs is that while they are said to encourage innovation, they may, in fact, contribute to a reduction in information flows and create a more secretive environment in the breeding sector. Whether IPRs have actually reduced sharing among breeders in Canada is the topic of the subsequent sections.

5.3 Survey Outline: Data Collection

Personal interviews with wheat and canola breeders served as the basis for assessment of IPR-related issues in the breeding industry. Each interview followed a semi-structured set of questions and breeders were welcomed to discuss the impacts of IPRs on their research programs. The survey questionnaire consisted of forty-seven questions covering the research profile of the interviewee, IPR policy at the institution, and experience in providing or accessing research inputs from the public and private sector. The interview responses provided insight into the effect of intellectual property rights on idea and knowledge sharing, germplasm flows, and cooperation among researchers.

Prior to conducting the personal interviews, approval from the University of Saskatchewan's Behavioural Ethics Committee was required. Approval of the study's procedures for data collection, storage, and use, as well as guidelines for respecting interviewee's anonymity, was granted on 13 October 2006.

5.3.1 Interview Process and Participation Rates

Interviewees included wheat, barley, canola breeders and IP officers in Western Canada. Interviews with wheat and barley breeders were administered by Viktoriya Galushko, a Ph.D. student, while those with canola breeders and IP officers were conducted by Emmanouil Oikonomou, a master's student at the University of Saskatchewan.

Potential interviewees were contacted through email. The Interview Consent Form (see Appendix B), specifying how the interview would proceed and how responses would be used, was sent to breeders prior to their decision whether to participate. The survey questionnaire was emailed to participants prior to the interview, so as to allow them time to compose their thoughts and provide more informed answers.

Every effort was made to conduct interviews with all wheat and canola breeders working in Western Canada. The list of wheat breeders was obtained from the Prairie Recommending Committee for Wheat, Rye and Triticale (PRCWRT) 2006-2007 report. Eleven of the sixteen people currently engaged in wheat breeding in Western Canada and three of the ten barley breeders agreed to participate in this study. On the canola side, nine breeders and two IP officers were interviewed. All the barley breeders, six canola breeders, and eleven wheat breeders came from the public sector (the University of Saskatchewan, University of Alberta, University of Manitoba, and AAFC). Personal interviews were arranged with seven of the wheat and barley breeders, all the canola breeders, and two IP officers, while the rest of the interviews were conducted by telephone.

Interviews began in December 2006 and concluded in March 2007. Each interview took about sixty minutes. To ensure an accurate rendition of the responses, the interviews were audio recorded and transcribed. Transcriptions were emailed to the interviewees for review and editing. Along with the transcript, the Interview Transcript Release Form (see Appendix C) was emailed or faxed to every participant to allow interviewees to select their preferred level of anonymity. Seventy percent of respondents in the wheat sector chose to remain anonymous, while all but one in the canola sector preferred not to be identified.

As was indicated in the Interview Consent Form, the interviewee could drop out of the study without penalty at any time. Two interviewees withdrew at the final stage (one wheat and one canola breeder), and one did not respond to a request to sign the Transcript Release Form, thereby making his interview responses ineligible for use in this study. As a result, the results of only twenty-three interviews (nine wheat breeders, three barley breeders, nine canola breeders, and two IP officers) are employed in this study. Because the wheat and barley breeding industries are similar in terms of technological structure (both wheat and barley transgenic engineering is not common) and funding structure (almost all research is publicly financed), both sets of breeders are referred to as the wheat industry for purposes of analyzing the responses. In the analysis, the canola interviews are referred to as Transcript C and the wheat and barley data as Transcript W, along with a number to denote particular transcripts.

5.4 Interviewees' Research Profiles

This section reviews the research profiles of the respondents. Research profile includes the number of years in crop breeding, techniques used (biotech or traditional), and the number of developed varieties and research tools. These qualities may affect the ability of the breeder to access research inputs and negotiate licenses. A profile summary is presented in Table 5.3.

Only one respondent has been breeding for less than five years, while thirteen have been in business for more than sixteen years, meaning that they were breeding before the introduction of PBRs. A majority of wheat breeders (ten of twelve) employ traditional breeding techniques, and only two have been using biotechnology in their breeding practices. The application of

Table 5.3: *Research profile of the respondents*

	Wheat sector	Canola sector[1]
	Frequency	Frequency
Number of years in breeding		
< 5	1	0
5-10	3	2
11-15	1	2
16-30	5	3
30+	2	2
Breeding technique		
Traditional	10	2
Biotech	0	3
Both	2	4
Number of research projects in the past 5 years		
1-5	4	5
6-10	5	2
11+	3	2
Number of varieties released every year		
Average	0.88	1.38
Number of research tools invented		
0	6	1
1-5	3	4
6-10	2	2
11+	0	2

[1] *Source*: Oikonomou (2007)

biotechnology in the canola sector is more popular, with six out of ten breeders adopting biotech breeding.

Respondents in both sectors stated that an emphasis is placed on applied research, which includes the development of research tools, germplasm, rust resistance research, and others (Table 5.4). On average, wheat breeders spend 8% on basic research, 63% on applied research, and 29% on development, including commercial variety development. Canola breeders allocate a larger portion of research funds to basic research. The average values for respondents in the canola breeding industry are 21% for basic research, 48% to applied research, and 31% for development.

The ability to access research inputs developed by others most likely depends on researchers' possession of research inputs. Among the wheat breeders, only five indicated they have invented research tools,[1] most of which were not patentable. Among the canola breed-

[1]Research tools include transgenic seeds/plants, vectors, markers, cell lines, antibodies, drugs, patented genes, and databases.

Table 5.4: *The structure of research funding of the interviewees*

	Wheat sector	Canola sector[1]
	Frequency	Frequency
Structure of research funding		
Basic research		
0%	3	2
1-20%	7	2
21-40%	1	3
41-60%	0	1
61-80%	0	0
81-100%	0	0
Mean	8%	21%
Applied research		
0%	0	0
1-20%	3	2
21-40%	0	1
41-60%	2	3
61-80%	2	1
81-100%	4	1
Mean	63%	48%
Development		
0%	3	5
1-20%	3	0
21-40%	2	0
41-60%	0	1
61-80%	3	2
81-100%	0	0
Mean	29%	31%

[1] *Source*: Oikonomou (2007)

ers, only two have never invented a research tool, while others have invented at least two research tools.

Summarizing, then, both the wheat and canola breeders seem to have a diverse research profile. The application of biotechnological techniques is common in canola breeding, while wheat researchers still employ predominantly traditional breeding techniques. Genetic engineering gives more scope for developing research tools, which is reflected in a larger number of research tools (subject to patentability) invented by the canola breeders compared to the wheat breeders.

5.5 Survey Results

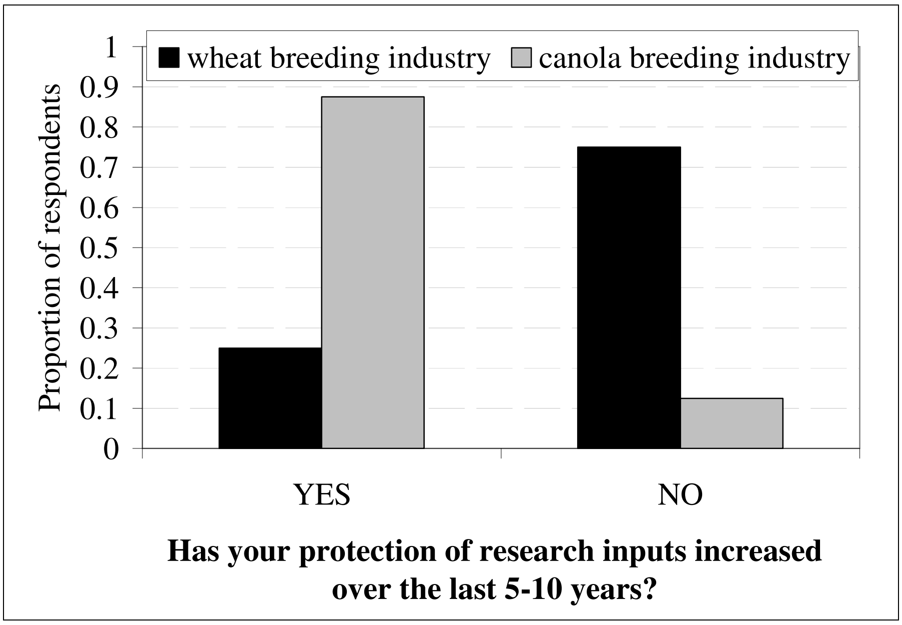
5.5.1 Vehicles to Protect IP in Plant Breeding and the Main Reasons for Protection

Previous chapters have mentioned that the Canadian Patent Act makes no explicit reference to plants, as has been shown by recent court decisions regarding higher life forms, including plants. Even though the patenting of life forms remains a very sensitive issue, a system has been established to provide IP protection to plant breeders in Canada. In this study's sample, the main measures to protect germplasm in the wheat breeding community were PBRs and MTAs, while PBRs were identified as the main tool to protect developed varieties. A number of breeders also identified genetic fingerprinting as a mechanism to protect germplasm. While genetic fingerprinting does not offer protection per se, it is used to characterize a material patent file or PBR file, and it allows the developer to identify its material and go after infringers. In the wheat research industry, patents are not common and are usually applied to germplasm with disease resistant traits, germplasm for semi-dwarfs, and NIR spectroscopy for quality selection. Only four out of twelve wheat breeders have applied for a patent, with a total of five patent applications over the past five years. None of the wheat breeders hold patented research tools.

In the canola sector, the use of DNA modification techniques and the relative simplicity of the hybridization process has meant that a larger range of IP protection mechanisms are available for both germplasm and developed varieties. Compared to the wheat sector, a greater effort seems to have been invested in the development of research tools in the canola industry, most of them patentable. Five canola breeders have applied for patents within the last five years, for a total of thirty-two patent applications.

As IPRs have proliferated following the expansion of the private sector and IP fragmentation, researchers have become aware of the importance of protecting their inventions. Respondents were asked whether the protection of research inputs has increased over the last five years. The results are illustrated in Figure 5.2.

The difference between the wheat and canola sector is salient. Only 25% of the wheat breeders reported increased protection of research materials, while almost 90% of the canola



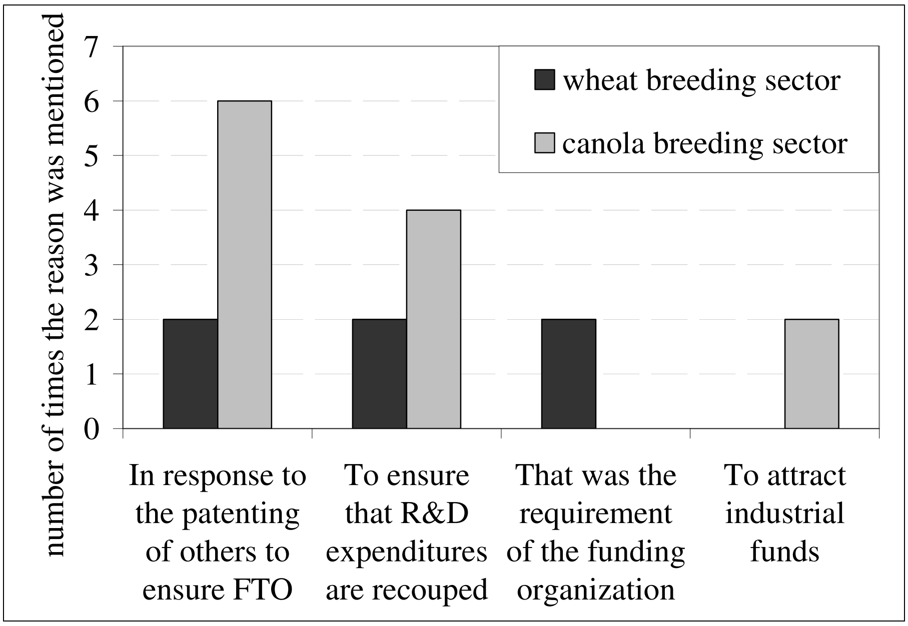
Source of canola data: Oikonomou (2007)

Figure 5.2: Protection of research inputs

respondents reported an increase in IP protection. One wheat breeder, for example, said that "my protection of germplasm increased over the last 5-10 years. Now we always have to use MTAs for any kind of germplasm we release" (Transcript W8).

Respondents were asked to identify the main reasons for a shift to stronger IP protection. Their responses and their relevance are given in Table 5.3. Two wheat breeders mentioned that the protection of research inputs was strengthened in response to the patenting of others. Another wheat breeder, however, ranked this reason as the least important. Recouping R&D expenditures was a major concern in the wheat breeding community. In contrast to the wheat industry, the major reason for increased IP protection in the canola industry was as a defensive measure to ensure FTO and to use IPRs as a bargaining chip in negotiations with other IP holders.

A number of breeders pointed out that patenting in the private sector is essentially different from patenting by public institutions. The public sector may patent research tools to prevent profit-seeking behaviour in the private sector and to ensure that Canadians derive the economic benefits from publicly developed technologies. One wheat breeder supported this: "We are a public institution and patenting allows public access to technology where if the technology was patented by the private industry it might be encumbered. In other words



Source of canola data: Oikonomou (2007)

Figure 5.3: Reasons for increased protection of research inputs

patenting by public institutions makes the technology accessible" (Transcript W4). One IP officer stated that "any technology released for the public good is just a give-away and it enables others to benefit and exploit the technology for their own economic benefit with little return to the Canadian taxpayer" (Oikonomou (2007), Transcript C4). The canola sector can serve as a good example of misappropriation of the public knowledge. When Canadian public institutions first developed canola, the seed was freely distributed. Now, however, large multinational companies engage in varietal development and have the same competitive advantage as the public sector, but this competitive advantage comes from the public sector's technology (Oikonomou (2007), Transcript C4). Another canola breeder brought up a case where a public canola variety, Westar (not protected by PBR), was supplied to Monsanto. The private company then incorporated their own herbicide gene into Westar and claimed ownership over the "new variety," ignoring any challenges from the original developers (Oikonomou (2007), Transcript C7). Furthermore, as private seed companies see enormous profit-generating opportunities, the public sector is excluded from variety development. As one public canola breeder pointed out, "there was lobbying from private industry in Ottawa against us [public researchers] producing varieties and competing with private industry" (Oikonomou (2007), Transcript C2).

Publication in journals has been mentioned by some as a way of managing IP. Some respondents considered publishing to be a defensive effort: "If you have something that is not patentable, publish it, put it in the public domain to prevent patenting by others and then you should have access to the market" (Oikonomou (2007), Transcript C1). Some breeders believed that publishing can keep a competitor from filing a patent. One IP officer, however, disagreed. He stressed that "patenting is about commercial utility and you cannot in a scientific journal describe commercial utility. So, even if you publish, someone can patent your work and then you will have to license it back" (Oikonomou (2007), Transcript C4). One canola breeder confirmed this, citing an example where researchers "essentially tried to publish on yellow seed but there were two companies who patented on yellow seed even though there were massive amounts of public disclosure" (Oikonomou (2007), Transcript C10).

5.5.2 Technology and Germplasm Sharing

One hundred years ago, nobody owned germplasm. Farmers and breeders freely exchanged germplasm and knowledge. The importance of sharing of knowledge and germplasm is reflected in the development of the Marquis wheat variety in Canada (Beingessner (2004)). It was developed as a cross between Red Fife and Hard Red Calcutta. Nearly every variety of wheat grown in Canada today is a descendant of Marquis wheat (AAFC). The wheat industry in Canada would not have achieved today's production levels without the cooperation of farmers from Poland, Ukraine, Scotland, India, and the United States, as well as with the cooperation of researchers within Canada (Beingessner (2004)).

The Marquis wheat example demonstrates how, in the absence of intellectual property rights, the free movement of germplasm and knowledge contributed to the establishment of a strong wheat industry in Canada. Introduction of IPRs, however, has the potential to reduce germplasm and knowledge flow. Beingessner (2004) provides an illustrative example of this, the story of Larry Proctor and the yellow bean. Larry Proctor owned a small seed company and was president of POD-NERS, L.L.C. He purchased a bag of beans in Mexico in 1994 that he claims were cream-coloured and with a yellow hue. Proctor decided that the yellow colour was a desirable characteristic and applied for an American patent on 15 November

1996, barely two years after he purchased the beans (Shand (2000)). He also obtained a plant variety protection certificate for his beans. The patent claimed exclusive monopoly on any *Phaseolus vulgaris* (dry bean) having a seed color of a particular shade of yellow. At that same time, an entrepreneur named Becky Gilliland owned a small yellow bean operation, Tutuli Produce, which imported yellow beans that had existed in Mexico for centuries to sell to Mexican immigrants. As the patent holder, POD-NERS demanded royalties of six cents per pound on the yellow beans entering the United States from Mexico. This stifled Tutuli Produce's operations, as well as any other commercial activity involving yellow beans. Because the patent granted to Proctor was so broad - encompassing almost all beans of any shade of yellow - there were serious repercussions on germplasm sharing and use. Public seed banks like the Center for International Tropical Agriculture (CIAT) were demanding that researchers in the United States and elsewhere sign agreements not to use the yellow seed for commercial purposes. It is unlikely that breeding institutions will undertake any research involving yellow beans if they know *a priori* that the results cannot be commercialized. In this way, Proctor's patent has restricted the use of yellow bean germplasm and blocked any research in this area.

Another story relates to the canola sector in Canada. Canola was developed by Canadian public breeders who worked with descendants of a rapeseed variety brought over by a farmer from Poland in 1927. Research efforts in the 1950s through to the 1970s aimed at developing a new type of rapeseed that could be used to produce edible oil brought about a variety with low erucic acid and low glucosinolates. Prior to 1985, there was little concern about the ownership of the product or process, which resulted in an unimpeded flow of genetic material and information among breeders (Carew (2000)). However, the canola sector in Canada has undergone a lot of changes since 1985. Nowadays only a few technologies allow free access, and patents or trade secrets protect most advances. From 1986 to 1997, 264 canola patents were filed, of which 118 were biotechnology innovations (Carew (2000)). As Table 5.2 demonstrates, free technologies in the canola sector are currently very limited.

There is no doubt that IPRs have reduced the quantity of research inputs freely available to the breeding community. To gain insight into this issue, the breeders were asked to estimate the proportion of research tools/germplasm freely accessible to them. A summary of responses is presented in Figure 5.4.

In comparing the wheat and canola sectors, it becomes apparent that the canola sector's access to research tools/germplasm is more restrictive (formal), with private industry in both sectors being least likely to provide research material without some kind of agreement or licensing scheme. In the wheat industry, roughly seventy-five to one hundred percent of research tools/germplasm is freely accessible. In the canola sector, one interviewee argued, "almost everybody in our industry can see the fact the freely available material for release without any burdens has dried out. So, we are really locked in a point where 1995, 1998, and 2000 was the last time where you could freely access material or germplasm" (Oikonomou (2007), Transcript C1). Another canola breeder from AAFC shared the same thought, asserting that "we will come to a point where knowledge, germplasm that is available from here [public organizations], would be exhausted to the extent that companies have more" (Oikonomou (2007), Transcript C4).

An important aspect in plant breeding is when research materials become freely available. As was pointed out by one canola breeder, "eventually most of germplasm becomes freely accessible but if it is the first time you hear about something you probably will not be able to access it. You have to wait longer. It used to be that in wheat it was agreed among wheat breeders that once the germplasm entered the co-op testing we could use it. Now you have to wait until a variety is registered. And the same with the canola varieties, once they are registered, you can use them according to the breeder's exemption under the PBR Act except for ones that have patented traits" (Oikonomou (2007), Transcript C9). One wheat breeder reported that "one, certainly, does not always publish information on the research tool or germplasm early in the game because you want to exploit it yourself before you have to share it" (Transcript W5). He also pointed out that sharing comes sooner within government institutions, while university researchers very often wish to complete their own exploitation of the material before they give it to others (Transcript W5). One interviewee underlined that "information does tend to be withheld for a period of time, eventually it becomes public, but it is being withheld for some time so that people who have done research or the sequencing can take advantage of it. It puts you in a disadvantage to other programs doing similar type of research" (Transcript W9).

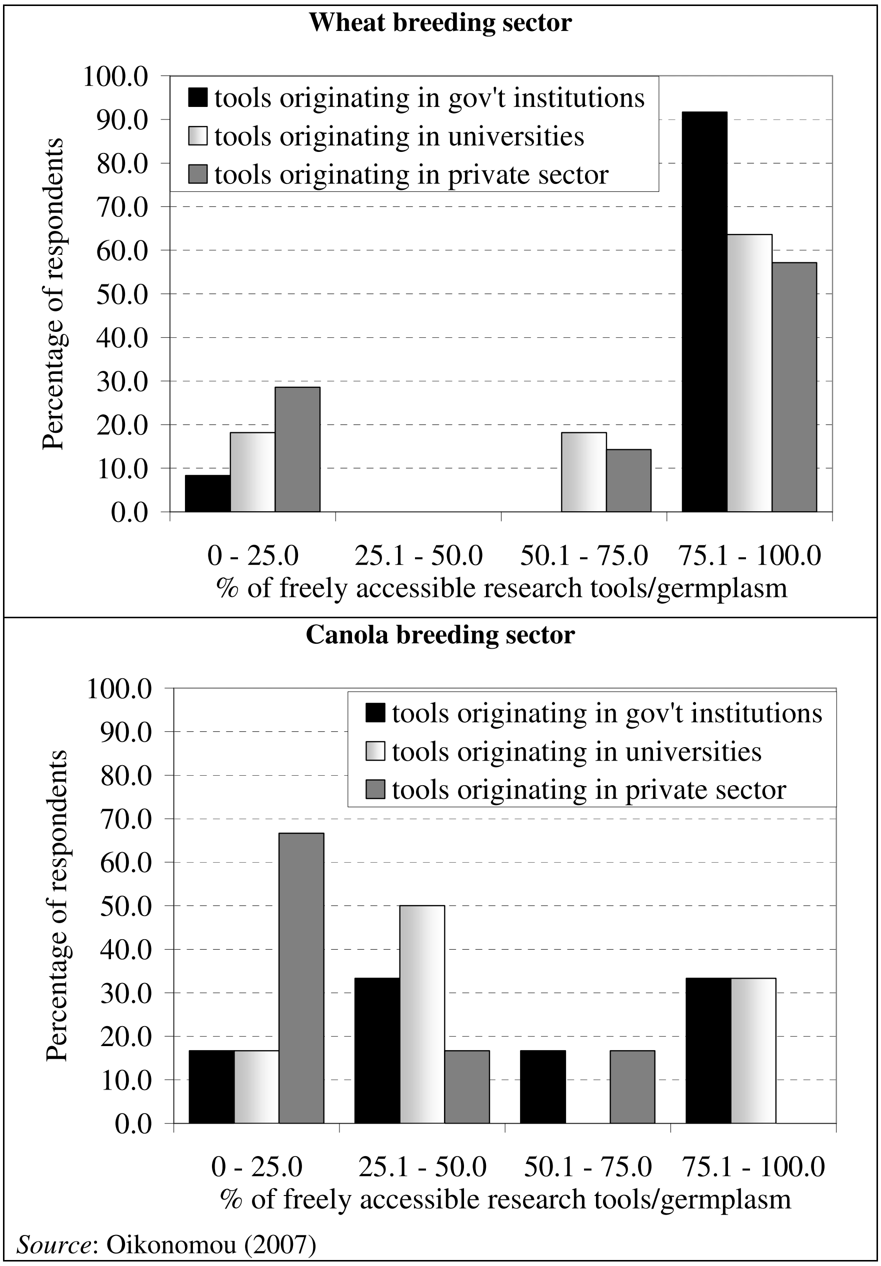


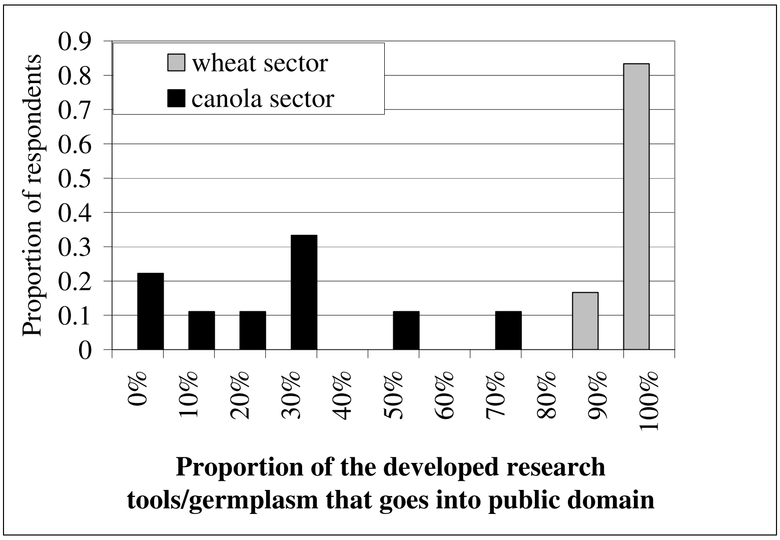
Figure 5.4: Accessibility of research tools/germplasm by crop and breeding institutions

Researchers were asked to share their views regarding the dissemination of knowledge/germplasm within the breeding community. The wheat and canola breeders had widely divergent views on this topic. Ten wheat breeders (83% of the respondents) strongly agreed that knowledge/germplasm should be freely distributed among researchers, while two agreed (i.e., they gave it a 2 on a 7-point scale, where 1 meant strongly agree and 7 meant strongly disagree). In contrast, two canola breeders strongly disagreed and three disagreed. On average, canola breeders rated the matter at 4.17 - somewhat disagree - compared to 1.16 for the wheat breeders. A public canola breeder stated that germplasm should not be freely distributed among breeders because private sector money is involved in its development (Oikonomou (2007), Transcript C2). Another breeder argued that "for the most part germplasm should be freely available. However, the insertion of a novel or a foreign gene that is patentable should be allowed protection due to the very expensive and lengthy requirements to get the necessary approvals for use" (Oikonomou (2007), Transcript C7).

Compared to the canola breeders, the wheat breeders were more willing to disclose their inventions. The breeders were asked to assess the statement, "You are unwilling to disclose your inventions and share them with other researchers." Eight wheat breeders located themselves at 7 (strongly disagree), with a 6.42 (disagree) average for the wheat sector. The average for the canola sector was somewhat lower, 4.29, suggesting a greater reluctance of the canola breeders to share their inventions with others. A public canola breeder stated that "after I have protected them [inventions] there is no problem [sharing]. That might even allow me to get licenses and so on" (Oikonomou (2007), Transcript C2). In the wheat community, most breeders realized that "it is difficult to make headway hiding information because there are so few people doing wheat work" - it is beneficial for everyone to share (Transcript W8).

These results suggest that the general view in the canola breeding community is that some restrictions should be placed on the flow of germplasm/knowledge among researchers. In contrast, the wheat breeders are oriented towards a more open exchange of technologies.

Figure 5.5 shows the proportion of developed research tools/germplasm that is placed in the public domain. Most wheat breeders (83%) reported that all the developed material becomes public, while the remaining 17% said that roughly 10% of developed material is kept private. One wheat breeder stressed, "What the government develops belongs to the



Source of canola data: Oikonomou (2007)

Figure 5.5: Technology going into the public domain

Canadian taxpayer and one of our approaches is to leave as much as possible in the public domain" (Transcript W3). In the canola sector, the situation is drastically different. Two private breeders reported that nothing is placed in the public domain, and the responses from other breeders demonstrate that a large portion of the developed material becomes proprietary (Oikonomou (2007)).

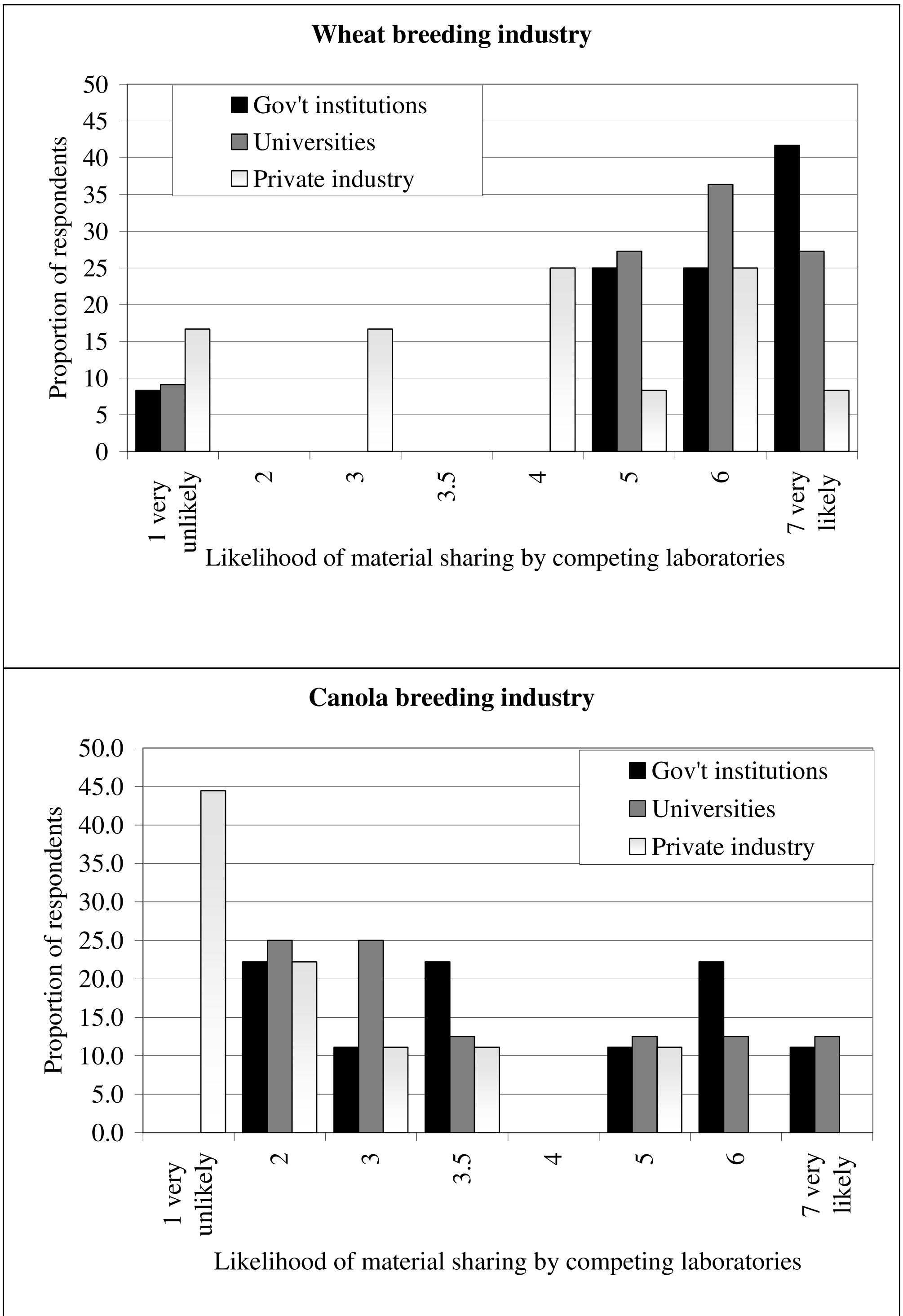
As private companies acquire more patents, public institutions become more aware of the importance of protecting their own research materials to gain a stronger bargaining power in the negotiation process and ensure greater freedom to operate. The result of increased protection on the part of both private industry and the public sector has been an enclosure of generated knowledge and reduction in sharing of research materials (Streitz, Bennett (2003)). The exchange of research materials between private companies and public institutions/universities is likely to be more problematic than public-public or private-private exchange due to the divergent incentives of these research entities. Private companies aim at commercializing new technologies, while public institutions and universities do not have a strong "commercial arm," which makes private firms less likely to cooperate or partner.

Even though there has been a shift to making upstream technologies proprietary, more so in the canola industry, some degree of sharing should still be expected within the breeding community. Because the breeding companies are not self-sufficient in breeding technologies, they should allow at least partial access to their technologies to ensure access to others' technology. To assess the extent that unwillingness to share with other researchers is a problem, respondents were asked, "How likely is it that the laboratories competing in the same field would provide the research tool/germplasm if you asked for it?" The results are illustrated in Figure 5.6.

Sharing of research materials among breeders in the wheat sector does not seem problematic. Government institutions and universities are most likely to share their material. This is supported by some interviewees' claims that public institutions are obliged to provide germplasm/tools to whoever asks for it, with the exception of private companies that want to use the material to develop a proprietary product. As one wheat breeder said "Within Canada we should be providing germplasm to whoever asks especially to other public organizations. For private industry we have to be more careful what they are going to do with it: is it going to go off shore? For example, will the company also have a breeding program in Australia or the US the major competitors in the wheat market? So, by being slow in sharing genes we can slow them down for a year or two but we will share" (Transcript W7).

Sharing is less likely within the private wheat industry. One respondent stressed that "the smallest private companies are like [a] one-way street: if we give them something, we won't get something like a research tool in return" (Transcript W8). Another interviewee stated that "the private industry is less likely to share and it's getting worse. I think these gentlemen's agreements in the next few years are going to be very difficult and they will disappear at all" (Transcript W10). However, there are also cases within the public sector where research materials are not shared. Kuyek (2004) provides a detailed discussion of how IPRs undermine the free exchange culture that has been nourished by generations of plant breeders in Canada. His personal communication with Brian Rossnagel, a barley breeder at the University of Saskatchewan, reveals that an unwillingness to share the research results is also inherent to public breeders. There was an incident when AAFC researchers identified the genes for disease resistance, but refused to share these genes with others. After being pressured by the plant breeding community, AAFC agreed to share the gene, but only in the form of raw germplasm impossible to work with (Kuyek (2004), p. 23).

The pattern in the canola industry is completely different. There is much less sharing in



Source: Oikonomou (2007)

Figure 5.6: Sharing of research tools/germplasm by competing laboratories

any of the three types of institutions (i.e., private, public, university). That restrictions on research material exchange are not confined to the private sector was also substantiated by one canola breeder who confirmed that the AAFC's desire to capture the benefits from patenting and PBRs "have made the exchange of basic material much more difficult than it ought to be" (Oikonomou (2007), Transcript C7). Sharing has not only shrunk in quantity, but also in quality. As one canola breeder noted, "With all the changes in the patent system we don't tend to give our best material" (Oikonomou (2007), Transcript C6). Sharing is extremely limited at early stages of development, and the general tendency is to provide material only after IPRs have been applied. One interviewee asserted that "it is in the interest of researchers as well as the institution to protect the research before you give it to anybody. Once I have protected the invention I am willing to share it with others" (Oikonomou (2007), Transcript C6).

5.5.3 Views on Secrecy

King (1993) argues that as transnational corporations took over the plant breeding industry, patents and corporate secrecy became the norm. Even university scientists now have to compete for corporate funding, and do not share information among themselves. One of the reasons mentioned by the public and university breeders to justify keeping information secret was preventing the private sector from using valuable ideas, bringing them to life, and then patenting the results, thus undermining the ability of generating public benefits.

To get a sense of how IPRs affected the sharing of ideas within the breeding community, respondents were asked whether secrecy has increased over the last five years. As Figure 5.7 shows, the breeders generally agreed that secrecy has increased over the last five to ten years, particularly in the canola sector.

In the wheat sector, two-thirds of respondents believed that the research environment has become more secretive, while one-third reported no increase. While a majority of breeders believed that their colleagues hold discussions about their projects, a number of wheat breeders reported that the public nature of research in wheat breeding contributes to information disclosure: "at least in the wheat breeding world the majority of players are public institutions so there is no such degree of secrecy as with other crops" (Transcript W5). One

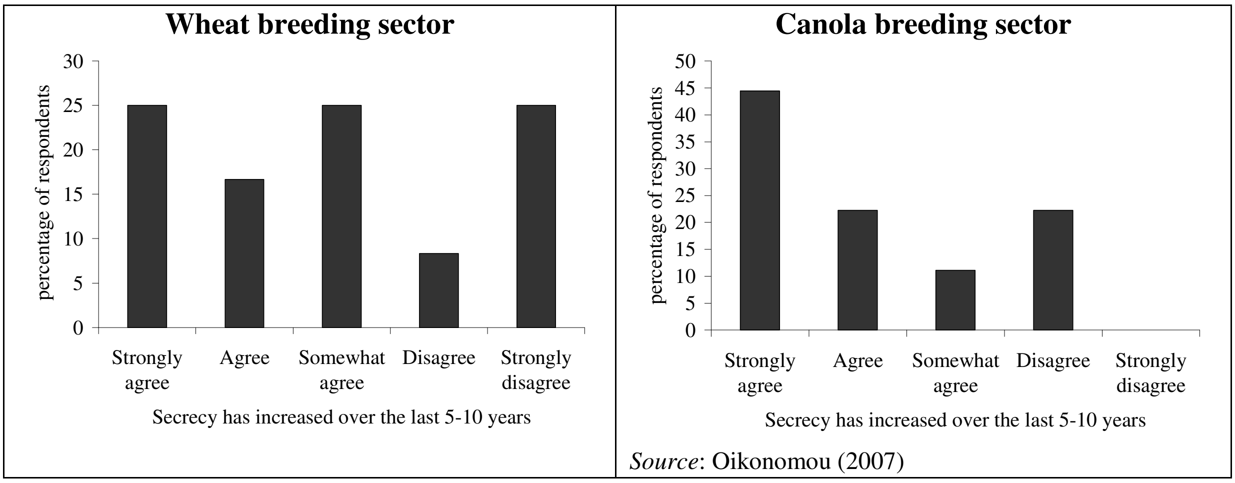


Figure 5.7: Views on secrecy in the wheat and canola breeding sectors

breeder, however, indicated that secrecy seems to be increasing and that some government grants (e.g., the WGRF grant) stated that “we have to approve what you are sending out in the public, we have to keep it secret until we feel we have gotten all out of it” (Transcript W9).

Responses from canola breeders leave little doubt that secrecy has increased: “Everybody knows what everyone else is doing but nobody talks about it. Secrecy has increased to ridiculous levels”(Oikonomou (2007), Transcript C5). A number of canola breeders have associated an increase in secrecy with the presence of private research industry. This is supported by the following comments:

“There are two groups of breeders. Public may talk to each other, private don’t. They don’t want others to know what they are doing, they don’t want to share it”(Oikonomou (2007), Transcript C10).

“When we collaborate with the private sector we have confidentiality agreements that we sign so that we can openly discuss what we have, what they are interested in, what kind of germplasm they might want to utilize from us” (Oikonomou (2007), Transcript C2).

Although it is clear that a vast majority of breeders do not approve of the poor level of information sharing, they seem left with no choice. Many research institutions’ policies prevent disclosure of information related to research, and the pressure to keep information secret comes from the business office. As one canola breeder pointed out, “A number of years ago we had canola meetings where the breeders would describe what they were working on. Now we don't say anything. We have prior knowledge here and we can't go and discuss it elsewhere because the business offices are concerned about patents and freedom to operate (FTO) issues" (Oikonomou (2007), Transcript C3). This same breeder reported a case of a visitor who wanted to talk to him, but the business office prevented the meeting out of concern that the guest would pass on information gleaned from observations (Oikonomou (2007)).

It is worth mentioning, however, that a number of canola breeders declared that the situation is beginning to change, that research organizations are undertaking steps towards faster disclosure of information. One IP officer stated, "What we try to do nowadays is to share everything; additionally what we do is we file as soon as we find something and we don't have the scientists wait until the patent issues, we let them publish/talk about it as soon as it is filed" (Oikonomou (2007), Transcript C4). This was confirmed by a canola breeder: "You can disclose as much as you can. Ten years ago our organization was encouraging us not to disclose anything but now if you cannot patent then you are encouraged to disclose as quick as you can" (Oikonomou (2007), Transcript C1).

5.5.4 Material Transfer Agreements (MTAs)

In the past, any germplasm/material exchange among breeders was fulfilled solely under understanding that a *"Code of Ethics"* would be followed. IPRs have dramatically changed the practice of exchanging germplasm. The exchange of materials in most cases is currently accompanied by MTAs, licenses, or other formal agreements. An MTA is usually sufficient for the transfer of technology because it outlines the exploitation of the research material. (Appendix D contains an MTA used by the Alberta Agriculture, Food and Rural Development for germplasm and cultivar transfers.)

In the canola sector, material transfers seem to be more formal than that of the wheat sector. Only three breeders out of twelve responded that cooperation with the private sector was formal (i.e., required signing of an MTA) in all cases, while three wheat breeders indicated that the collaboration was wholly informal. Collaboration with public sector institutions seems to be less formal, with two breeders indicating that they had to sign agreements in all

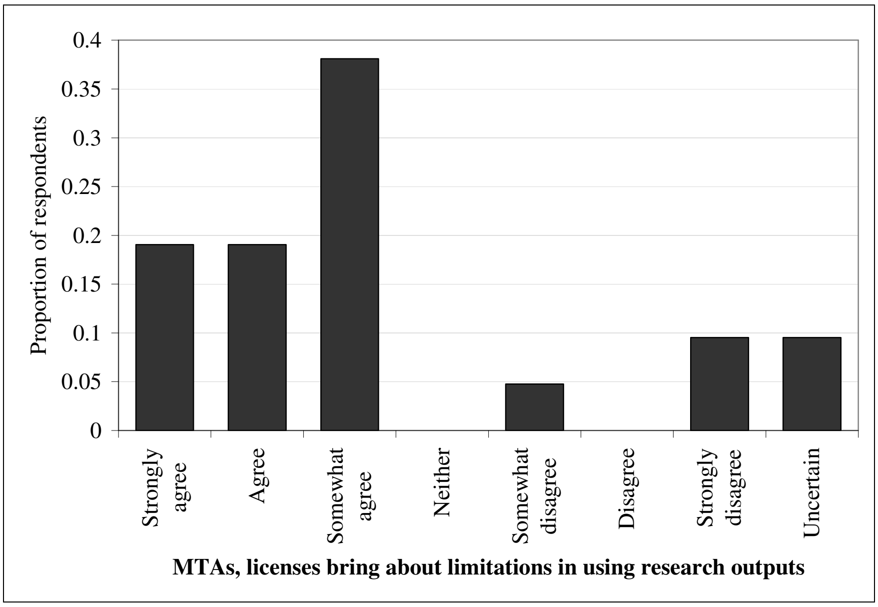


Figure 5.8: Legal arrangements (MTAs, licenses) and the use and dissemination of research outputs

cases, and seven breeders indicating that agreements were required less than twenty percent of the time. One interviewee said that IP offices require that a formal agreement be signed whenever a transfer of germplasm is conducted, but that breeders frequently miss this formal step (Transcript W2). One barley breeder noted that "everything is formal not because the breeders want it but because the institutions decided that it has to be this way" (Transcript W10). However, there are also cases where breeders initiate the MTAs. For example, one wheat breeder pointed out that "in all cases I am transferring germplasm I want to make sure that there is an MTA. It helps me track of what I have given and make sure that other breeders are using my germplasm appropriately for crossing" (Transcript W9). The breeder from the AAFC indicated that the legal procedures are "more set up now and there are not many unregulated transfers of germplasm. However, even though MTAs are required they don't mean to control where the germplasm goes" (Transcript W8).

Generally, MTAs are beneficial to those who initiate them because they reduce the risk of material being misappropriated. As one canola breeder indicated, "You can send your material for evaluation without the risk of misappropriation, so I think those are really facilitating" (Oikonomou (2007), Transcript C1). However, there are a number of concerns that have been raised in the public with regard to the use of MTAs. First, it is claimed that

MTAs can restrict the freedom of universities to publish and can prevent further research if the MTA specifies that the material provider owns all the results. One wheat breeder countered, "Universities do not sign agreements that limit publications. The longest time period that we might have a publication restriction would be six months" (Transcript W6). One university wheat breeder, however, indicated that there were a couple cases when he had to sign MTAs that prohibited publication of the results (Transcript W9).

A second concern claims that MTAs can also stifle valuable research initiatives. One canola breeder stated that very often MTAs give the sending party reach-through rights on any IP developed using technology covered by the agreement. Because the outcome of the research program is unknown in most cases, breeders are reluctant to put the material to possibly valuable use in order to avoid valuable discoveries being appropriated by the sender (Oikonomou (2007), Transcript C8). Furthermore, research initiatives may be quashed by MTAs because they make the whole process of material exchange cumbersome and extremely lengthy. The words of one canola breeder support this: "You can get a license from Monsanto, for example, to use their gene but it does not let you release a variety without strings attached such as the TUA requirement. MTAs are a little easier, they are not as tight, so they are not quite as much of a problem but one thing that is always there is the extra time and effort that it takes to get these things through both parties... [It] takes forever to get the two parties to come to some sort of an agreement" (Oikonomou (2007), Transcript C7). Very often there is a high degree of uncertainty about the outcome of the breeding program, and if the collaborator asks for an MTA the researcher might decide that it is not worth the effort and change the research agenda rather than go through the legal requirements (Transcript W5).

5.5.5 Impacts of Restricted Access

Restricted access to upstream innovation may generate significant costs to society in terms of lost opportunities for technological developments. While IPRs foster innovative activity in general, they discourage scientists getting involved in areas where a large portion of intellectual property is proprietary. As one canola breeder pointed out, "IP is becoming very aggressive, IP filing is happening extremely early in development projects. What it has done for us is reduced our research depth because we won't step in that pool if there is a potential patent out there" (Oikonomou (2007), Transcript C1). A number of breeders confirmed the negative effect of IPRs on development in the canola research industry:

"Germplasm exchange has become a particularly sensitive issue and unfortunately it has become, at least with canola, a real constraint to making significant industry wide improvements" (Oikonomou (2007), Transcript C7).

"We used to sit down at coffee and discuss our research. You don't dare do that anymore and from that perspective you lose something, you loose the outside view, a different perspective. You lose the opportunity to broaden your project or improve your project with that somebody new from pathology, entomology or genetics" (Oikonomou (2007), Transcript C7).

"What really cripples biotechnology today is patents on enabling technologies. For instance, the patent in Brassica transformation has probably caused tremendous damage to the development of science and also the development of new products in Brassica crops" (Oikonomou (2007), Transcript C8).

IPRs, Duration of Research and Delays

IPRs are often associated with increased duration of research. Even before a project is initiated, a researcher has to search for all possible IPs to learn which research inputs can be freely used and which are proprietary. When the proprietary materials are identified, the researcher has to negotiate the terms of use with the owners to ensure FTO in case the research output proceeds to commercialization. On occasion, it can take years before an agreement is reached and all pieces of IPs are obtained.

Respondents were asked whether stronger IP protection had increased the length of time to complete a research project. Fully two-thirds of the wheat breeders and nearly two-thirds of the canola breeders stated that, yes, the duration of research has increased. One canola breeder commented, "I think it has increased significantly because we are dealing with MTAs or having to get things signed. It just seems to take longer. The paper work takes lots of time and in order to get a sample of material or germplasm it takes more time" (Oikonomou (2007), Transcript C3).

The respondents were also asked to identify the number of projects that suffered delays and the longest delay that they had encountered. On the wheat side, four out of twelve breeders reported delays, with a maximum delay of three months. Although none of the reported delays seemed significant, some of the breeders stressed that, taking into account the extra time required to complete a project, research programs suffered: "For one program it took us three months from when we signed an MTA to when we got the IP. The total time to complete the project was four years but it was a very intense project. So, even though three months out of four years does not sound too bad it did set us back in terms of our time lines and objectives" (Transcript W9).

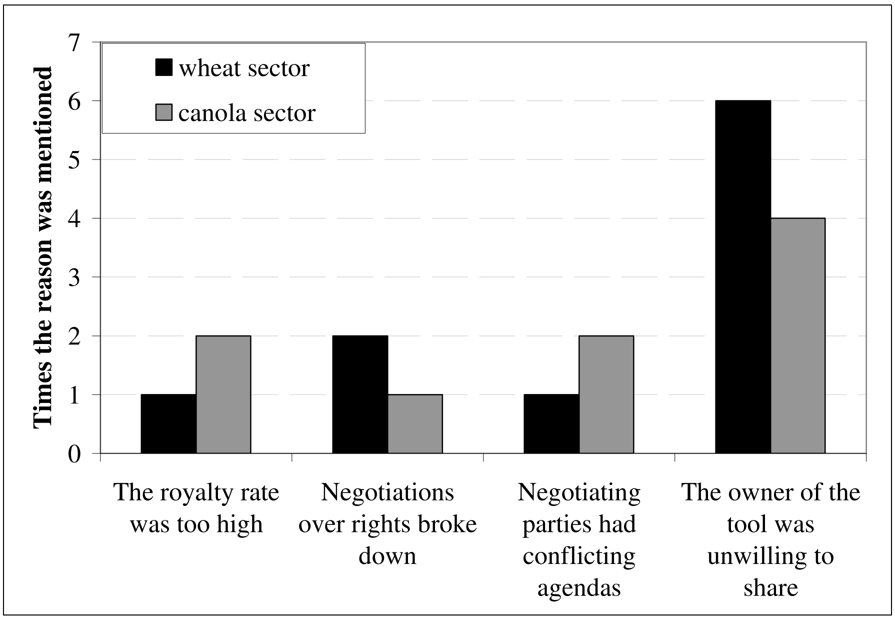
The problem seems to be more prevalent in the canola sector. In many cases, negotiations last for months, even years, and inflict significant delays and costs on research programs. Out of nine canola breeders, six identified cases where their research programs were delayed. One canola breeder, for example, said that "there was one case that took 3 or 4 years. Just because of the inability to negotiate with the competitor" (Oikonomou (2007), Transcript C1). One canola breeder reported a research delay of five years (Oikonomou (2007), Transcript C9).

Many breeders reported that they had never had to negotiate any IPs because they tended to stay away from protected materials and limited their choice to publicly available research inputs. One canola breeder stated, "I don't think I was ever delayed in what I wanted to do because I never had to obtain IPs. But the time it takes for commercialization of that research is certainly longer . [I]t may take years to negotiate agreements" (Oikonomou (2007), Transcript C2).

Blocked Access to Innovations

The possibility of extracting rents from innovations created by IPRs encourage private breeders to withhold access to their breeding lines and use them as bargaining chips in negotiating collaborations with other private companies. Firms also block access to their best technologies in order to slow down competitors (Phillips (2000)).

Respondents were asked to identify examples where the inability to obtain all necessary research tools/germplasm led to a project's cancellation. One-third of the wheat sector interviewees responded that they had had research projects that were abandoned due to an



Source of canola data: Oikonomou (2007)

Figure 5.9: Reasons for not being able to obtain research tools

inability to access research tools/germplasm. In the canola sector, this number was 55%. One specific case mentioned by the wheat breeder was a collaboration with Monsanto that led to number of events dropped because an FTO could not be obtained (Transcript W7).

The reasons why researchers could not get access to the necessary research inputs were also examined. As Figure 5.9 shows, the most commonly mentioned reason is that the owner was simply unwilling to share the technology, that there was no possibility of negotiating the terms of use. One canola breeder mentioned a case where one party was unwilling to share because, as a public company, they did not have a commercial arm (Oikonomou (2007), Transcript C5). A wheat breeder reported that he once was looking for permission to use a specific trait for a breeding program, but the private company that owned the trait refused to share because it did not feel that the crop that it would be used in was important. "So, the private company thought they would not make enough money from the innovation utilizing the trait and they did not share it" (Transcript W4). Another interviewee said that "the owner of the tool was unwilling to share the tool - they just told us that there was a competition" (Transcript W2). One canola breeder shared his concerns, adding, "What I would like to see is that anyone who has a patent has to license it at a reasonable cost. I think a lot of people don't even try to license... and that has been probably the biggest problem in the canola industry" (Oikonomou (2007), Transcript C9).

As Heller and Eisenberg (1998) mentioned, very often the tragedy of anticommons or inability to access research materials is due to cognitive biases - the developers overvalue their assets and, as a result, reject reasonable offers and deny requests for the research material. This was supported by one wheat breeder: "[In those cases when I cannot get germplasm] the private companies think that they have something so wonderful nobody has that they just do not want to share. But I have to admit that usually it is not the case" (Transcript W7). A barley breeder indicated that in the past AAFC refused to share germplasm a couple of times because they believed that they had something very valuable and could pay for the research projects off their inventions (Transcript W10). "The problem with that was that they never learnt the value of the material because the only way to find out whether there is any special value is to give it to other people and let them try it, which they did not" (Transcript W10)

The breeders were also asked to identify cases where they denied a request for a research tool/germplasm. In the wheat/barley sector, only one barley breeder could cite an example, and the reasons cited were commercial concerns and the contract forms with the funding organization: "One of the breeding lines that we produced in collaboration with Company X had restrictions about it. And it is not that it was not available but it is that everyone who wanted to use it had to obtain a permission from Company X. So, we were participating in a situation where we had to deny a request for a research material but it is one in a billion cases" (Transcript W10). In the canola sector, 55% of the breeders stated that they had denied a request for the material in the past, most frequently citing "contract forms with the funding organization" as the reason.

5.5.6 IPRs, Collaboration and Plant Breeding

Stronger IPRs may serve as an incentive for the public sector to enter into collaborative agreements with private industry. On the one hand, these collaborations have a potential to increase public research efforts by offering more funds for research and providing access to proprietary technologies owned by the collaborators. An experimental agreement signed between the Novartis Agricultural Discovery Institute and the University of California at Berkeley in 1998 illustrates this point. The agreement specified that Novartis would provide Berkeley with $25 million over five years for basic research in agricultural genomics, as well as provide access to DNA databases and proprietary technology (Klotz-Ingram and Day-Rubenstein (1999)). On the other hand, collaborative agreements, and public-private agreements in particular, can change the research agenda of public scientists, where greater emphasis is placed on industry goals rather than on research that might yield long-term benefits for the breeding industry.

Survey respondents were asked about the impact of collaboration on their research programs. In the canola sector, the public breeders generally confirmed that collaboration with the private sector has been beneficial for their programs and for the industry as a whole. One public canola breeder asserted that collaboration with the industry had "enabled [us] to continue the work with dwindling federal research funding, especially after 1995 and a series of cutbacks. The outside funding allowed us to do research that is of value to Canadian agriculture. MII funding allowed us to prepare the next generation of germplasm that we could offer to industry" (Oikonomou (2007), Transcript C2). Other interviewees supported the idea that public-private collaborations have made significant contributions to the development of public canola breeding programs:

"We certainly are able to expand our program in terms of platform technologies that we are developing" (Oikonomou (2007), Transcript C3).

"It [collaboration with the private industry] has made us vastly more productive and the technology transfers much quicker" (Oikonomou (2007), Transcript C8).

"Working with industry in collaborative projects is always rewarding because industry works in a different way. So you get very good feedback on how to utilize the tools" (Oikonomou (2007), Transcript C11).

Collaboration with the private industry in the wheat sector is limited because there are not too many private firms conducting wheat research. One wheat breeder, however, pointed out that collaboration with small private firms did not have any impact on the research agenda, but it helped create more value out of the program by sharing and putting germplasm to better use (Transcript W8). Another breeder indicated that collaborations have contributed to more rapid development of research tools such as DNA markers (Transcript W5).

Thus, breeders generally deemed collaborative agreements with the private sector as beneficial to their research programs, enabling better utilization of available technologies and easier access to proprietary technologies. At the same time, concerns that private participation skews research towards applied areas seem unsubstantiated, as none of the canola and wheat breeders mentioned that such collaborations shifted research priorities away from basic research areas.

Even though the general view is that collaboration with the private sector generates greater research funds, some breeders suggested that collaborative agreements may actually limit the possibilities for public researchers to raise funds. One canola breeder asserted that "we get into problems when we get tied up with the company we are doing collaboration and then other companies come along and want to work with us, but we can't because of restrictions or agreements" (Oikonomou (2007), Transcript C3). To deal with this problem, breeders try to avoid any kind of restrictive agreements. As one canola breeder pointed out, "Often our contribution to research collaboration from the germplasm standpoint is the non-exclusive use; we don't go into collaborations where we commit ourselves with a unique line of germplasm exclusively for collaboration with that company as we want to use that line as we see fit" (Oikonomou (2007), Transcript C2).

There are increasing concerns that public-private collaborations are influencing the IP protection policy of public institutions, as some of those agreements may contain an article requiring the protection of all IP coming from the use of private funds. Alternatively, agreements may specify that the private collaborator holds the right to license the developed technology, which may result in restricted access to upstream innovations by public scientists, thus hindering technological progress (Klotz-Ingram and Day-Rubenstein (1999)). The Novartis-University of California agreement, for example, gave Berkeley ownership of any discoveries made under the contract, but, in return, Novartis would have the first opportunity to license about 30-40% of any inventions made in the school's Department of Plant and Microbial Biology (Klotz-Ingram and Day-Rubenstein (1999)).

The wheat and canola breeders were asked to identify any changes in the IP protection area that had occurred due to collaboration with other researchers. One public canola breeder said that "PBRs was something that industry funding required us to do and more and more interest in patenting the technology that comes out of collaboration with the industry partner" (Oikonomou (2007), Transcript C2). In general, canola breeders agreed that enclosure of research work and collaboration with private industry go hand-in-hand. A number of canola breeders stated that confidentiality agreements sometimes prevent researchers from publishing results coming out of the projects funded by private industry. However, public canola breeders have undertaken significant efforts to ensure that at least some portion of knowledge becomes public: "With collaborative agreements with industry it is not possible to distribute the data although we ensure that certain non-confidential aspects of the project work can be published" (Oikonomou (2007), Transcript C11). Another canola breeder provided an example of negotiations with a private collaborator that involved the possibility of publishing the genetic linkage data. This negotiation began because of a request from the Brassica genetic research community that indicated that making available the markers data would be beneficial to the community. The final agreement with the private industry on the Brassica Single Nucleotide Polymorphism marker project made publicly available one-third of the sequence data generated, with the other two-thirds remaining proprietary (Oikonomou (2007), Transcript C11). It was also mentioned that, generally, "proprietary information cannot be released to the public domain for 10-15 years" (Oikonomou (2007), Transcript C11).

There is also some evidence that collaboration with the private sector may have some repercussions on the release of the technology. One wheat breeder provided an example where collaboration with a private company in Manitoba gave the company "the right to first refusal of the licensing of the variety" (Transcript W3).

5.5.7 The Potential for a Research Exemption

In order to limit the adverse effect of patents on subsequent innovative activity, patent laws in many countries explicitly incorporate research or experimental exemption. In 1993, Canada amended the Patent Act to include a statutory exemption. The Act states that it is not an infringement to make, use, or sell a patented invention "solely for uses reasonably related to the development and submission of information required under the law of Canada, a province or a country other than Canada that regulates the manufacture, construction, use or sale of any product" (Canadian Patent Act). In 2004, the Canadian Biotechnology Advisory Committee issued an Advisory Memorandum to the federal government to specify more clearly the research exemption in the Patent Act. The proposed statement was (Smyth (2006)):

It is not an infringement of a patent to use a patented process or product either:

a. privately and for non-commercial purposes, or

b. to study the subject-matter of the patented invention to investigate its properties, improve upon it, or create a new product or process.

The potential for a research exemption as in American patent legislation is also worth noting. Even though the American practice has no automatic value as precedent in the Canadian courts, in several instances American IP policy has influenced Canadian law and policy (Smyth (2006)). Because the process of obtaining patents is much faster in the United States, Canadian inventors prefer filing their application in the United States first. Thus, it is important to know whether Canadian breeders can use material patented in the United States for experimental purposes, especially taking into consideration that the developed technology will then be exported to the United States.

Previously in the United States, it had been thought that if research was conducted at a publicly funded institution, that status alone might garner the protection of the exemption. A recent precedent, Madey v. Duke University (2002)[2], however, showed that there is no experimental exemption under the American legislation.

Some observers have argued that "research exemption" is vaguely defined in the Canadian legislation. The problem with the research exemption is that it is difficult to draw the line between experimental and non-experimental use. Universities, for example, are engaged in the production of both basic knowledge and plant varieties. At some stage plant varieties have to be distributed to farmers, which is considered commercialization. This type of research activity no longer falls under "the use for research purposes only," even if the university is not distributing the variety for money-generating purposes.

To see whether the scientists believed that there was a research exemption, they were asked the following question: "As a breeder, do you have a research exemption for protected

[2]In this case Madey, a professor who ran an experimental lab at Duke University and resigned in 1998 after he was replaced as director of the lab, sued the university for infringing his two patents. The US patent court has interpreted a research exemption in a narrow fashion and ruled that university research is not exempt from liability for patent infringement

(patented) material?" Only four out of twelve wheat breeders said that they could use the protected material under the research exemption clause, while only one canola breeder agreed that a research exemption exists in the Canadian system. One wheat breeder offered, "We use patented processes without licenses and it is just a part of our normal operation. There are theoretically patents on double haploid technologies and things like that and we use them as part of our normal research process but I have never bothered to get a "formal" exemption because we are allowed to use those while we are doing research" (Transcript W6). One canola breeder indicated that "there is no research exemption and if we know that there is a patent out there, that there is the possibility that covers our material then we would like not to touch it" (Oikonomou (2007), Transcript C1). Another canola breeder said, "I believe that the present PBRs legislation specifically allows breeders to use PBR registered varieties in their breeding programs but the industry has taken the stand that you need the company's agreement to use their varieties in other breeding programs" (Oikonomou (2007), Transcript C7).

5.5.8 Access to Offshore Germplasm

Access to off-shore germplasm has played a significant role in establishing the Canadian wheat breeding industry. As mentioned above, had it not been for the collaboration of researchers from Poland, India, the United States, and other countries, Canada's wheat economy would not be what it is today. Thus, whether changes in IPRs worldwide affected the wheat breeding industry in Canada was of great interest. A number of breeders stated that a number of countries are beginning to restrict access to their germplasm collections. While material exchange with Eastern European countries have not been affected by changes in IP laws, some of wheat breeders mentioned that the developing world has tightened up their regulations: "What has happened and this goes back to other places is that a lot of countries now, especially the third world countries where we used to get germplasm very easily, absolutely refuse to allow anything to go out without a major agreement. And that has really limited the exchange of germplasm without even getting involved with major companies" (Transcript W2). A number of breeders mentioned that the nature of germplasm exchange with Australia has changed dramatically, something which can be explained by the establishment of private industry in Australia's wheat breeding sector. Nowadays, Australia requires MTAs for any kind of material exchange (Transcript W5, Transcript W1). One wheat breeder mentioned a case where his group had tried to access some disease resistant material that the Australian federal government agency controlled. The condition that the agency put forward for its use of completely unadapted material was 40% of any royalties, which was unacceptable. The inability to access that resistance gene resulted in the project's cancellation (Transcript W11).

5.5.9 Working Solutions to FTO Issues

Private property rights should, in theory, enable firms to exploit and benefit from their innovation, but in practice the fragmentation of rights can pose serious threats to both private and public benefits. One of the most pressing issues for many companies is the freedom to operate in a world of overlapping and interwoven claims to intellectual property (Phillips and Onwuekwe (2007)).

One prominent example of a freedom to operate issue is pro-vitamin rice A, ($GoldenRice^{TM}$), which was investigated by Kryder et al (2000). Depending on the country where the new technology would be used, there were between zero and forty-four patents that could be applied to the product. In total, the authors report that the development of $GoldenRice^{TM}$ would involve about seventy pieces of IP spread across about forty institutions and fifteen instances of tangible property rights. Although Monsanto, Zeneca, and others agreed, after a year of negotiations, to provide royalty-free licenses for the development and distribution of this innovation in developing nations (Walsch (2003)), and the researchers proceeded with their initial idea, this case demonstrates how complex subsequent research can be when inputs are privately owned.

Researchers who are engaged in cumulative research are well aware that if they commit to investment before the freedom to operate is obtained, this will weaken their bargaining position should the innovation proceed to commercialization. That is why, in general, an extensive search of patents for technologies that might have IP is performed before the project is launched. Four canola breeders mentioned cases where they developed a variety/research tool before the FTO was obtained. In one case, the issue was resolved by destroying the invention because the owners of research inputs did not want to negotiate. In others the solution was reached by redirecting the project to invent around the patent and hooking up with the industry partner who had FTO (Oikonomou (2007), Transcript C6, C8, C9, C4).

Potentially, a number of problems can be avoided if the scientists know which IPs are proprietary and can negotiate agreements before a project starts. However, the difficulty arises from the fact that it can take years for a patent to be granted. Therefore, at the time that the research program is launched, the researcher may be unaware that a patent has been filed and is under review. This leads to situations where, if a substantial R&D effort has been invested, researchers find themselves with few options. What options do plant breeders employ to overcome a lack of FTO?

One response of the public breeders was to protect their intellectual properties and use them as bargaining chips during negotiations with private companies (Phillips (2000)). Developing a "corporate technology toolbox" is a strategy employed by Agriculture and Agri-Food Canada (O'Sullivan (1999)). "When we develop and patent a new piece of technology we look at the best way to license it to protect freedom to operate," says O'Sullivan, the president and CEO of Ag-West Bio Inc. "The important thing is to determine how we want this piece of technology marketed in the best interest of the industry, both public and private. Our underlying philosophy is to promote the global competitiveness of Canadian industry and the Canadian Agri-Food sector". Another possibility is to negotiate collaborative research agreements with companies holding critical patents. As O'Sullivan indicated "Getting them to pay for part of the research cost that puts useful technology in the hands of our industry will help us compete internationally" (O'Sullivan (1999)).

When negotiations break down, there is always a possibility for researchers to carry on with the project, ignoring all IPs. "You can ignore the patent issue and hope that the patent holders will not litigate, but that is a very risky strategy," says O'Sullivan (1999). One IP officer put forward the idea that "sometimes we just ignore the IP because generally the patents of others have more of an impact when you want to commercialize the research as opposed to just doing basic research" (Oikonomou (2007), Transcript C4). One barley breeder indicated that they can use patented technology without permission from the patent holder as long as whatever is produced is not transgenic: "We can use the patented technology and that is where you gamble: when you register a variety you do not have to disclose what technology you used to produce it unless it is transgenics. For example, I use the technique called X and it has some IP stuff on it that corporate Canada would be concerned about. But when we register a variety there is no requirement and no reason for us to indicate that it was how we got Y into it and we never did. In our case there was no way that they [the patent holders] could ever prove that we used their technology, so we could just go away with it" (Transcript W10).

5.5.10 Views on the Efficiency of Knowledge Transfer

There are two sides to the IP protection system. The positive side is that IP protection encourages innovations, while the negative side is that downstream research efforts are undermined as protection of upstream innovations proliferates. It is impossible to design an IP protection system that would only yield benefits in the form of increased R&D. Any system is a combination of good and bad, so the goal is to establish a system that balances the two, that stimulates innovative activity and ensures the best use of germplasm or knowledge that is out there. Is the system established in the Canadian wheat and canola research industries efficient or is it skewed towards over-protectionism or under-protectionism? The following discussion is addressing the performance of the current IP system by looking only at one side of the equation, which is, the efficiency of knowledge/information transfer.

Some breeders argued that the old system, with no IPRs, was the most efficient in terms of generating benefits for the breeding community. One canola breeder echoed this belief: "When I started wheat breeding there was no agreement or anything, it was done freely and that was a great system" (Oikonomou (2007), Transcript C9). However, even today within the wheat breeding community, there is agreement that the current IP system works relatively well in terms of dissemination of research technologies. One wheat breeder mentioned that "the current system makes the best use of germplasm/knowledge because the exchange and flow of germplasm is still quite fluent. We do have these MTAs but they don't really preclude people from using germplasm" (Transcript W8). Another wheat breeder put forward the same type of argument: "There is a lot of sharing currently. There tend to be these delays so that people can take advantage of their knowledge and I do it myself but I think that though the current system is not perfect it is functioning well in terms of sharing" (Transcript W9). Not all wheat breeders, however, support this point of view. Some argue that "there has been gradual erosion in access to and free sharing of germplasm, which certainly limits access to the new traits that have been identified" (Transcript W5).

The situation is different in the canola sector, where all the breeders support the view that the current IP protection system leads to too much knowledge/technology enclosure. Some of these breeders indicated that the reduction in technology/information flows observed nowadays is a result of the early patents that had very broad claims across species, rather than the source-specific patents applied today (Oikonomou (2007), Transcript C1). One canola breeder pointed out that the current system "is a little bit too much towards super-protectionism and blocking from having market access. If we could pull back a little bit then initial developments could have access to the market" (Oikonomou (2007), Transcript C1). A shift towards excessive protection is also supported by the following remark: "We cannot get registered varieties out of most breeding institutions without signing an MTA. And yet, we can go to the elevator and for $100 buy the seed in bulk. Clearly things have gone too far in the direction of protectionism" (Oikonomou (2007), Transcript C5). Another canola breeder claimed that "the current system does not make the best use of germplasm simply because part of it has been separated off into patented positions and so that some germplasm has become very difficult or impossible to access" (Oikonomou (2007), Transcript C7). Yet another stated that protection "has closed down a wide sharing of germplasm amongst the whole range of breeders" (Oikonomou (2007), Transcript C10).

While most canola breeders agreed that knowledge could be disseminated more efficiently without an IP protection system, some also argued that "then we would generate knowledge only to a certain point because even knowledge generation requires money" (Oikonomou (2007), Transcript C2), and the private industry and IPRs associated with its establishment are important sources of research funds. A number of canola breeders pointed out that even though the current system is a hindrance to research technology exchange, it has yielded benefits to society in the form of new technologies that would never have been developed had there not been IP protection in place.

The current IP protection system has also been mentioned as requiring too much duplicative effort. One wheat breeder raised this point: "I don't think that the current system is efficient. And again, not so much in wheat because in wheat things are still pretty much public and available. But I watch with my canola colleagues and essentially they are having to re-invent molecular mounts because they are not sharable. So they spend thousands and even millions of dollars on re-developing molecular mounts they could have acquired out of Saskatoon but they cannot access them because there is no proper sharing agreement or because it is too expensive to acces" (Transcript W6). This raises a natural question: are there benefits from having the private industry involved in research and having stronger IPRs? IPRs are expected to attract more private investment, thus buttressing limited public research funding. But the reality is that IPRs reduce access to available technologies and lead to a large portion of a scarce resource - research funds - being allocated to performing a lot of work over and over again.

5.5.11 IPRs and the Future of Plant Breeding

A number of canola breeders indicated that the United States Patent Office has already made a move to limit the scope of awarded patents to ensure that overly broad claims do not block subsequent research. This has facilitated access to and the use of patented materials (Oikonomou (2007), Transcript C8, C10). "That wide patenting has been a real problem in the past and I am glad to see it is gone" (Oikonomou (2007), Transcript C10). "Also there are several major Universities creating a sort of a club of high technology organizations to make a common pool of enabling technologies. The main idea is that there will be a large common depository of enabling technologies, so in the future the only things that will limit freedom to operate are patents at the very end of the invention chain."[3] (Oikonomou (2007), Transcript C8). One breeder also pointed out that when entering collaborative agreements with the private sector, their organization now attempts to increase the proportion of the developed technology released for the public use. He stated that in the future they are planning to place about sixty-five percent of the developed technologies into the public domain, as compared to the current thirty percent (Oikonomou (2007), Transcript C8). Another canola breeder

[3]The Public Intellectual Property Resource for Agriculture (PIPRA) is an example of a large common depository of enabling technologies. It brings intellectual property from universities, public agencies, and non-profit institutes to make their technologies freely available around the world.

indicated that “this [negotiating with private industry to increase the portion of technologies going into the public domain] is a normal thing that we do with the new projects, to ensure that a portion of the sequence data will be publicly available” (Oikonomou (2007), Transcript C11). He also emphasized that expressed sequence tags (EST) collections in the wheat and soybean industries were made publicly available and that this trend is starting in the canola industry. “There is one canola EST collection in AAFC and one in Plant Biotechnology Institute (PBI) in Saskatoon and this summer a large number of these ESTs are going to become publicly available” (Oikonomou (2007), Transcript C11).

Thus, there is evidence that participants in the canola industry and patent offices have come to realize that the current system is not working properly in terms of information and research material flows, which limits the abilities of research organizations to make industry-wide improvements. A new era seems to be beginning in the canola industry, one of narrowing down patents to breeding lines in order to facilitate access to existing technologies. “There has been a history of private funding in the canola industry and this established a trend where the majority of data has remained proprietary. But recently there has been a global trend to try to make plant breeding resources publicly available; this is also affecting the canola industry by encouraging more open exchange of information” (Oikonomou (2007), Transcript C11).

In contrast, there was a strong consensus within the wheat breeding community that that sector is moving towards more IP protection. One breeder reported that the wheat research industry “is heading towards more and more protection of IP. I am seeing a lot more applications of IPRs. IPRs become the part of the mandate or part of the requirement of federal organizations and universities and we are seeing more of it” (Transcript W6). A second wheat breeder said that “as time goes on it will be more difficult to access germplasm with the traits that we need to solve the problems or issues that we need to solve through genetics” (Transcript W4), while a third stated that “I suspect there will be stronger and stronger protection developing over time in case of wheat” (Transcript W5). A fourth breeder echoed the above statements: “We will see more protection in plant breeding except in wheat that process will be a slower one taken into consideration that wheat research is public” (Transcript W3).

5.6 Conclusions

This chapter has endeavoured to assess whether protecting IP poses a serious threat to the breeding community in the form of restricted or blocked access to upstream innovations. The interviews confirm that freely accessible materials have shrunk over the last few years and that the number of cases where legal arrangements are required to obtain research tools/germplasm has grown. Most material exchange is now fulfilled through MTAs that specify the rules for the use of the transferred material and ownership of the research results. In most cases, MTAs are not impediments to germplasm exchanges between breeders. However, they tend to make the exchange process more cumbersome and lengthy.

The canola and wheat sectors show different patterns in terms of information/material exchange. In the wheat sector, where participants are primarily public entities, the degree of sharing of genetic materials is rather high and a majority of breeders agreed that about seventy-five to one hundred percent of materials are still freely accessible. The canola industry, dominated by the private sector, is marked by increasing secrecy and a general unwillingness of researchers to share research tools/germplasm. In many cases, the unwillingness to disclose research-related information is dictated by the patent (business) offices rather than the actual breeders. In general, the responses confirm that, while most materials eventually become freely accessible, sharing is still very limited. In the long run, this has the potential to slow down progress in the Canadian plant breeding industry.

There is evidence that negotiation and licensing impose additional costs in the form of delays that are hindrances to the industry-wide developments. IPRs on research inputs have not only contributed to delays in research, but have also been the reason for project cessations. Forty-two percent of the breeders reported cases where projects had to be canceled due to an inability to access upstream innovations. Again, the problem is more acute in the canola industry.

Reduced information flow and tools/germplasm exchange is, in part, a result of the protection system under which the biotech companies and breeders operate. The Canadian patent system needs greater integrity and clarity as to what is patentable and what is not. Uncertainties about patent eligibility encourage companies to keep information/materials secret rather than assign property rights and make the invention available via a licensing fee. This, in turn, stifles subsequent innovation and leads to costly duplicative efforts.

The canola breeders' responses support the view that the current IP protection system is not efficient in terms of knowledge dissemination, and that there is a bias towards over-protectionism. This finding is consistent with the results in the theoretical model in Chapter 4, suggesting that there is an incentive to protect every piece of IP. But, as several canola respondents mentioned, this situation is changing. There is a general tendency to narrow patent claims to reduce the probability of infringements, thus promoting the use of upstream innovations. Furthermore, public institutions are undertaking significant efforts to increase the amount of information going into the public domain. The participants from the wheat breeding industry, however, indicated that there is a growing trend towards more IP protection in their field.

Even though only two sectors, namely canola and wheat, have been considered in this work, some of the results can be generalized to other crops. For crops where private involvement is currently dominant such as soybeans and corn the conclusions drawn from the canola sector can be applicable. Furthermore, we might expect that in the future crops that are important on the international level such as wheat, barley and certain pulse crops will follow the IP patterns observed in the canola industry as conventional breeding methods are replaced with biotech breeding. Therefore, these sectors are likely to face the same issues that are currently faced in the canola industry. For minor crops such as oats it is reasonable to expect that breeders will be sharing ideas and research materials with each other irrespective of increased application of biotechnology tools since the play field for these crops will consist of a very limited number of breeders, thus making cooperation a survival strategy.

Chapter 6

CONCLUDING COMMENTS

6.1 Summary and Conclusions

This dissertation has addressed a number of issues essential to farming and plant breeding communities in Canada. In particular, an analytical framework was proposed to examine the effect of plant protection in the form of Plant Breeders' Rights (PBRs) and patents on incentives to perform varietal development and on the distribution of benefits from research. Interviews with plant breeders were conducted to explore the impact of intellectual property rights on the willingness of researchers to share information/research materials with their colleagues, the ability of plant breeders to access existing technologies to conduct research, and freedom to operate. The remainder of this section presents a synopsis of the work.

The history of intellectual property rights (IPRs) in agriculture in Canada and the world is compiled in Chapter 2. That chapter discusses the international developments that have framed Canadian IPR policy. These include: the foundation of the International Union for the Protection of New Varieties of Plants (1961), which introduced Plant Breeders' Rights as a mechanism to both foster innovative activity in the breeding sector and safeguard the interests of farmers by preserving their right to save seed; the Trade-Related Intellectual Property Rights agreement (1994), which was initiated by the industrialized world and aimed at preserving the rights of innovation-rich countries via the granting of patents; the Convention on Biological Diversity (1993), which was initiated by the developing world to protect the rights of bioresource-rich countries; and the International Treaty on Plant Genetic Resources for Food and Agriculture, which aimed at ensuring an equitable sharing of benefits arising from the use of genetic resources. The history of plant protection in the United States, Europe, and Australia is also presented to provide perspective about Canada's standing among the developed countries in terms of plant IP protection.

Chapter 3 presents an analytical model to assess the differences between patents and PBRs with respect to their potential to encourage innovation and the implications for farmers' welfare and the distribution of benefits from research. The research industry is modeled as monopolistic, with one life science firm developing a new variety and selling it to heterogeneous farmers. It is assumed that the technology yields some benefit to farmers, in the form of reduced production costs, higher yield, better quality, for which farmers receive a premium. The behaviour of both the firm and farmers is modeled in a three-stage game. In the first stage, the life science firm decides on an R&D effort that determines the degree of improvement over the generic variety. The second stage encompasses the first period (year) after the introduction of the new variety to farmers. In this stage, farmers make their adoption decisions and the life science company chooses the pricing strategy. The final stage covers the second period (year), after the release of the new variety. The second period adoption and pricing decisions are modeled in this stage. To incorporate the difference between two forms of plant protection, under PBRs the farmers can decide whether to purchase the seed in the second stage and use harvested seed for reproduction purposes in the third stage, while under patents the option of saving the seed is eliminated.

The model is used to develop a number of propositions:

Proposition 3.1. *The seed price charged by the monopolistic seed company in Stage 2 will be higher than the price in Stage 1 if farmers' reproduction costs are above a specific threshold.*

Proposition 3.2. *When the technology is protected by patents and farmers can learn about the new technology from adopters, the seed company will charge a lower price in Stage 1.*

Proposition 3.3. *Patents do not guarantee better varieties. If seed production costs for the seed company are at least the same as the price of the generic variety then the company will not invest into R&D.*

Proposition 3.4. *Seed company's profit, farmers' welfare, and total welfare decline as the costs associated with the adoption of the new technology (parameter λ) increase.*

Proposition 3.5. *Farmers' welfare decline as the cost of saving (reproducing) the seed* *rise.*

Proposition 3.6. *Innovation efforts under PBRs are higher than under patents when farmers' reproduction costs are below a specific threshold.*

Profit-maximizing innovation efforts under PBRs and patents are also determined. It is shown that one cannot say unambiguously that patents are more effective in stimulating innovation. Depending on the research firm's marginal cost of seed production relative to farmers' seed reproduction costs, PBRs can be as effective as patents in fostering innovation. As for the distribution of benefits from adopting the new technology, the simulation results reveal that farmers capture a smaller share of the pie under patents than under PBRs, but the benefits accruing to farmers under a patenting regime are not necessarily smaller in absolute terms.

The life-science company's welfare depends on seed production costs. If farmers' reproduction costs are lower, then the seed company is better off protecting its technology with PBRs, selling the seed to farmers, and letting them produce their own seed.

In Chapter 4, a game-theoretic model is developed to examine researchers' incentives to disclose/enclose knowledge in the world of IP protection. Along the way, a number of propositions are derived:

Proposition 4.1. *R&D effort will be the highest for a firm when it acquires access to the other firm's technology but maintains an exclusive right over its own technology.*

Proposition 4.2. *When two firms compete in a differentiated product, market they are both better off cross-licensing their technologies rather than enclosing their knowledge.*

Proposition 4.3. *When two firms compete in the differentiated product market and the symmetric licensing fee is below a specific threshold, both firms will have an incentive to enclose their technology, leading to a "tragedy of the anticommons."*

Proposition 4.4. *When two firms compete in the differentiated product market and the symmetric licensing fee is above a specific threshold, a cross-licensing equilibrium will be sustained and the social optimum achieved.*

Proposition 4.5. *When firms anticipate an enclosure equilibrium under IP protection they will have an incentive to protect their IP if protection costs are lower than the symmetric licensing fee.*

Proposition 4.6. *When firms anticipate a cross-licensing equilibrium under IP protection they will have an incentive to protect their IP if IP protection costs are lower than the symmetric licensing fee.*

Proposition 4.7. *If IP protection costs are lower than the licensing fee in equilibrium, then firms will move away from free sharing of knowledge/technologies towards IP protection.*

Chapter 5 presents the results of interviews with wheat and canola breeders to explore some findings from the theoretical model. The choice of sectors is not arbitrary. Wheat and canola are considered because they have followed divergent paths since the outset of biotechnology era, with rapidly expanding IPRs in the canola industry and relatively free information/knowledge flow in the wheat sector. It is found that the main reason that researchers patent their discoveries is in response to the patents of others. The possibility of patenting and, as a result, the risk of a hold-up by technology owners encourages the whole breeding community to move towards a more secretive and protective environment. The responses of breeders suggest that IPRs have generally led to a reduction in research material/germplasm flows, have increased secrecy in the canola industry to "ridiculous levels," and have discouraged scientists from getting involved in research areas where a large portion of the intellectual property is proprietary. The existence of a tragedy of anticommons in the Canadian breeding sector is supported by reported cases where access to some IPs could not be obtained and the research projects had to be dropped.

Overall, the canola breeders agreed that the research industry has moved too much towards protectionism and that IPRs have negatively affected germplasm/knowledge flows among breeders. In the wheat sector, IPRs have not gained as much significance as in the canola sector, and a lot of wheat breeders are still experiencing quite fluid germplasm/knowledge flows. Canola breeders' responses also indicate that the breeding community seems to have realized that too much protection limits the ability to conduct research, and there recently emerged a tendency to disclose knowledge and deposit more information in the public domain. In the wheat industry, on the contrary, the breeders are seeing greater use of IPRs.

6.2 Lessons Learned, Policy Implications and Caveats of the Study

This study has endeavoured to answer the following questions:

(1) How does IP protection of seeds affect the distribution of benefits and incentives to engage in varietal development? and

(2) How does IP protection of upstream innovations affect the ability to conduct downstream research in the plant breeding industry?

The analytical models developed in this thesis and empirical evidence enable us to learn some important lessons related to innovation and IPRs in agriculture in general, and Canadian agriculture in particular.

The analytical model developed in this dissertation has shown that the innovator views the nature of the product (new plant variety) differently under PBRs than patents. When the seed is protected by PBRs, seed-saving practices grant it a durable aspect and the seed developer adjusts his pricing strategy to take this into consideration. In other words, if the innovator knows that seed saving will generate some future rent, then he will try to appropriate this rent indirectly by charging a high price on the parent seed. Thus, while patents allow the seed developer to extract benefit from the farmer in every period, in the case of PBRs the innovation's future value is extracted after the technology is released to farmers. This leads to the conclusion that it cannot be stated unambiguously that PBRs are ineffective in encouraging varietal development. If seed production by farmers is more efficient than that by the seed company, PBRs are a more effective mechanism than patents in terms of innovation impact.

This study does not substantiate concerns that eliminating the farmer's exemption will erode farmers' benefits. In general, patents ensure a supply of better technologies, thus bringing larger total benefits. The implications for farmers' welfare is that, even though farmers capture a smaller *portion* of the benefits when the seed is protected by patents, the *absolute* gain is not necessarily smaller.

The analytical model employed to study the effects of IP protection on research incentives and producer welfare has a number of caveats. First, it is assumed that there is a perfect enforcement of IPRs. Concerns about seed saving surround the possibility of a farmer brown-bagging rather than use of the saved seed on his own plots. Under patents, farmers can also infringe and save part of the harvest for subsequent reproduction, which the model precludes. If farmers' incentives to infringe are the same, irrespective of the protection mechanism, then the results of the model would not be significantly affected. It is, however, unlikely to be the case. When patents protect the technology, implying that there is an identifiable trait built into the plant, enforcement of IPRs is more feasible because the innovator can identify his plant and prove infringement. In the case of PBRs, the enforcement is more costly because seeds of conventionally produced plants are difficult to identify. Under PBRs, proving infringement is likely to be more costly for the firm than under patents. Therefore, the probability that a farmer will be caught and penalized is probably to be lower under PBRs, thus encouraging more infringement. For this reason, PBRs can be a weak instrument to foster innovation. Further research will be required to study the incentive structure when the possibility of brown-bagging is incorporated into the system.

Second, the analytical model looks into the link between the two forms of IPRs and R&D effort, but only in terms of seed saving possibilities. The R&D decisions of a firm are also driven by rivals' imitation possibilities. When the technology is protected by PBRs, the protected variety can be used in other breeding programs without the owner's permission. As long as a new variety is distinguishable from the original, it can be protected and commercialized, which increases competition among the varieties and reduces sales of each particular variety. When patents protect the variety the "experimental exemption" clause ensures that it can only be used for research purposes and cannot be commercialized without license arrangements with the original variety's owner. Therefore, the probability of imitation is lower when patents protect the technology. For this reason patents can be a better mechanism to foster innovation. Studying the effects of patents and PBRs on innovation when there is competition from both farmers (through saved seed) and breeders (through imitation) is another topic for further research.

In this work, an effort has also been made to shed some light on the key aspects of IPRs and cumulative research. An important lesson learned from the interviewees' responses is that the possibility of patenting does indeed change the behaviour of breeders. Even public breeders, whose main purpose is to serve the general societal well-being, become overwhelmed in the process, and the whole breeding industry is moving towards a more secretive and protective environment. Sometimes access to research inputs is blocked completely and so promising research projects are abandoned.

It seems that the freedom to operate issue is becoming more acute in the breeding sector. Even though scientists generally try to avoid using proprietary materials in their research, which reduces the risk of a hold-up, a number of cases were reported where innovations had to be destroyed due to an inability to obtain FTO. However, researchers have been able to develop "working solutions" to FTO limitations. These include cooperating with industry partners, developing a "corporate technology toolbox," or simply ignoring patent issues.

When designing a system of IP protection in agriculture, the impact on all groups of society should be assessed, on plant breeders (both as developers and users of the developed technologies in subsequent research) and farmers. The optimal IPR system should balance the incentives to innovate and the right to exclude others from using the technology. In the wheat sector, it seems that the current system balances the interests of technology developers and users - it provides certain rules for using private knowledge while preserving relatively fluid flows of germplasm/information. The survey results suggest that the current system of IPRs in the canola industry is skewed towards excessive protection. There is a recent tendency, however, to disclose information as soon as a patent application is secured and increase the amount of knowledge going into public domain.

Combining the evidence from the wheat and canola sectors suggests that IPRs are a hindrance to efficient knowledge dissemination and research whenever application of biotechnology on a large scale with private participation is concerned. This points to the importance of government involvement with biotechnology to ensure that a strong research base is kept intact.

One limitation of the survey results warrants attention. While research funding in the canola breeding industry is predominantly private, the sample included only three private scientists. This may have skewed the interpretation regarding the accessibility of inputs and freedom to operate. Public breeders are mostly engaged in basic/applied research that produces inputs for downstream innovation, while the development and commercialization of final products (canola varieties) are left for private firms not included in the survey. Therefore, the freedom to operate problem might have been underestimated in the interviewees' responses.

Appendix A: The survey questionnaire

SURVEY CONTACT

Name:____
Title: ____
Name of institution: ____
Indicate type of affiliation with main institution ______________________________________

PART 1. IN THIS SECTION WE WOULD LIKE TO LEARN ABOUT YOUR RESEARCH PROFILE

1. How long have you been doing wheat/canola breeding?
YEARS_____________

2. Are you engaged in traditional or biotech breeding?
- o Traditional
- o Biotech
- o Both

3. How many research projects have you undertaken in the past 5 years? _________

4. Of the R&D funding that you have control over, what percentage goes to:

Basic research ________________%

Applied research is the development of research tools, germplasm, rust resistance research, breeding, etc.
Applied research______________%
Please, specify what type of applied research you do

Development _______________%
Development includes variety development, commercial development

5. How many new varieties of wheat/canola do you on average release every year?
# of new varieties ___________

6. Research tools include transgenic seeds/plants, vectors, markers, cell lines, antibodies, drugs, patented genes and databases

(a) How many research tools have you invented? ____________
(b) How many of them are patentable? ____________

7. Please, describe the research tools you have invented

PART 2. HERE WE ARE TRYING TO UNDERSTAND TO WHAT EXTENT THE INVENTIONS IN WHEAT/PLANT BREEDING ARE PROTECTED BY INTELLECTUAL PROPERTY RIGHTS

8. Who owns the intellectual property (including plant varieties) created at your institution?

- The institution owns it
- The researcher owns it
- Joint ownership: the institution and the researcher
- The funding organization owns it
- No policy on ownership

9. Have you (has your institution) engaged in any of the following forms of intellectual property protection over the last 5 years?

IP activity	Number
Filing of patent applications/provisional patent applications	
Filing of applications for plant breeder's rights	
Signing of non-disclosure agreements	
Other (please, specify)	

10. How many of the research tools that you have developed have been patented? ____________________

11. Of the tools that you have developed and patented, what proportion of the patents are held in:

US	Canada	Other

12. Which of the following have you used most frequently to protect germplasm?

- Trade secrets
- Patents
- PBRs
- Genetic fingerprinting
- Material transfer agreements

13. Which of the following have you used most frequently to protect developed varieties?

- Use of hybrid varieties
- Terminator technology (genetic use restriction technologies that confer sterility on re-planted seed)
- Trade secrets
- Patents
- PBRs
- Signing of technical use agreements
- Genetic fingerprinting
- Bag-label contracts

14. What percentage of new varieties developed by your institution is protected by plant breeder's rights since 1990?
_______________%

15. Has the number of applications for plant breeder's rights by you increased over the last 5 years?
- o YES
- o NO

16. Of the varieties you have developed and obtained IPRs to, what proportion of the patents/PBRs are held in:

US	Canada	Other

17. Generally do you agree that
- o Knowledge/germplasm should be freely distributed among researchers

  1____7
  strongly agree strongly disagree

- o You are unwilling to disclose your inventions and share them with other researchers

  1____7
  strongly agree strongly disagree

- o You patent/protect research tools that you develop because you are required to do so; otherwise you would not patent/protect

  1____7
  strongly agree strongly disagree

- o You (the seed distributor/company) always enforce your patents/PBRs, etc. against universities

  1____7
  strongly agree strongly disagree

  ☐ Never enforce ☐ Never had to

- o You (the seed distributor/company) always enforce your patents/PBRs, etc. against industry

  1____7
  strongly agree strongly disagree

  ☐ Never enforce ☐ Never had to

18. Has your protection of <u>research tools</u> increased over the last 5-10 years?

- YES
- NO

19. Why did you increase your protection?

- in response to the patenting of others to ensure freedom to operate
- to ensure that R&D expenditures are recouped
- that was the requirement of the funding organization
- other, please specify

PART 3. CONTRACTS AND COLLABORATIVE ACTIVITY

20. Do you collaborate with other researchers?

	Proportion of cases where you collaborate	OF WHICH	
		Proportion of cases where you collaborate formally (via MTAs, licensing schemes, etc.)	Proportion of cases where you collaborate informally
With the private sector			
With the public sector			

21. Has your collaboration increased over the last 5 years?

	Formal collaboration			Informal collaboration		
	Increased	Steady	Decreased	Increased	Steady	Decreased
With public sector						
With private sector						

22. How much outside funding have you received over the last 5 years?

- Percentage of total resources (including overhead and in kind) ________________%

- Dollar value _____________$

23. For this outside funding who were the sponsors of the R&D contracts undertaken over the last 5 years?

R&D supported by	Share in total value of contracts
Federal government	
Provincial Canadian government	
Foreign governments	
Large private firms	

Small private firms	
Royalties	
Grower groups	
Other (please, specify)	

24. What impact has collaboration had on your research program (e.g. crops, traits, processes)?

25. What impact has collaboration had on your intellectual property protection activity?

PART 4. ACCESS TO RESEARCH TOOLS OWNED BY ACADEMIA OR INDUSTRY

We would like to learn about the access to upstream discoveries essential to subsequent innovation.

Research exemption means that researchers are not liable to patent holders if they utilize patented technology during the course of their research without a license from the patent holder.

26. As a breeder, do you have a research exemption for patented material?

- YES
- NO
- NOT CERTAIN

27. For the two most important projects/programs you are working on, how many pieces of IP did you have to negotiate?
#_________

28. When you use research tools in your research how often do you look into their IP access:

- Never
- In _________% of the cases
- Always

29. How often do you use patented material or processes without a license?

- Always
- In______________% of the cases
- Never

30. Have there been any incidents where you developed a new variety/research tool before you had obtained freedom-to-operate?

- YES
- NO (skip to 32)

31. How was the issue resolved?

31. How was the issue resolved?
- o You obtained licenses for all IP
- o You had to destroy your invention
- o You re-directed the project to invent around the research tool patent
- o You ignored all intellectual property and proceeded with the commercialization of the product despite the allegations of the patent holder
- o Other, please specify

32. Have there been any cases where you could not get the research tools/germplasm and decided to cease the project?
- o YES
- o NO

33. If there were any cases when you could not obtain the research tools why did it happen?
- o the royalty rate was too high
- o negotiations over rights broke down
- o negotiating parties had conflicting agendas and you could not reach an agreement with all the rights holders
- o the owner of the tool was unwilling to share the tool
- o Other, please specify

34. Legal arrangements (MTAs, licenses) to get access to proprietary research tools bring about limitations in using and disseminating your research outputs.

1____7
strongly agree strongly disagree

☐ Uncertain

35. What proportion of the research tools you are using originated in

	Government institutions	Universities	Private sector
Proportion of the research tools			
Percentage that are freely accessible			
Percentage of proprietary tools*			

* By proprietary tools we mean tools access to which requires MTAs or licensing

Sharing your intellectual property with other institutions

36. What proportion of research tools you have developed goes to the public domain?
____________%

37. Have you ever denied a request for a research tool?

- YES
- NO

38. If you don't provide the research tools/germplasm, what is the major reason for not sharing the information?

- concerns about scientific competition (you wanted to protect the scientific lead)
- the expense and scarcity of the materials
- commercial concerns
- contract forms with the funding agency
- requirement of your institution
- other, please specify

39. Secrecy (unwillingness to discuss current research with others) has increased over the last 5-10 years?

1____7
strongly agree strongly disagree

☐ Uncertain

40. How likely is it that laboratories, which compete with you in the same field, would provide research tools/materials if you ask them

- ✓ Government institutions

1____7
Very unlikely
very likely

☐ Uncertain

- ✓ Universities

1____7
Very unlikely
very likely

☐ Uncertain

- ✓ Private industry

1____7
Very unlikely very likely

☐ Uncertain

Part 5. The costs and benefits of stronger IP

In this section we would like to learn about the costs associated with managing and obtaining IP as well as the possible benefits of clearly defined IP rights.

41. What are the costs associated with obtaining IP?

a) Compared to 5 years ago, how many more days per month do you spend managing your IP?

_________________ days/month

b) Does this cover
- an equivalent amount of IP:
  - o Yes
  - o No
- an increased amount of IP:
  - o Yes
  - o No

c) Compared to 5 years ago, has there been an increase in the number of persons involved in IP management in your organization?
  - o Yes

- the number of persons involved in managing IP 5 years ago ____________
- the number of people involved in managing IP today _____________
  - o No

d) What is the approximate size of this increase in cost?
______________$/year __________________% of total budget

e) Compared to 5 years ago, do you require more IP related services (e.g., lawyers, IPR officers, negotiators)?
- o Yes
- o No

f) If your institution has had to hire IP services (e.g., lawyers, IPR officers, negotiators), what are the costs in terms of time and money?

	Time	Cost	Cost
5 years ago			
Researcher	months	CND $	% of total budget
Institution	months	CND $	% of total budget
Program	months	CND $	% of total budget
currently			
Researcher	months	CND $	% of total budget
Institution	months	CND $	% of total budget
Program	months	CND $	% of total budget

g) Has the length of time that research takes increased due to stronger IP protection?
  - o Yes, it significantly increased
  - o Yes, it somewhat increased
  - o No

h) How many programs suffered research delays because of the difficulties in obtaining IPRs from others?
___________ out of total ___________ programs

i) What was the maximum delay that you experienced in obtaining IPRs from others?
________________days/months
________________% of total time required to complete the project

42. What are the benefits of having stronger IP?

a) Are there instances where IP rights reduced transaction costs? [Transaction costs are the costs associated with obtaining and managing IPRs, including time lost because of the need to obtain IPRs.]
  - o Yes, please specify
  - o No

b) Have there been any instances where clearly defined IP rights sped up the time the research took?
  - o Yes, please specify
  - o No

c) Are there any instances where IP rights increased your ability to invent/work around?
  - o Yes, please specify
  - o No

d) Are there any instances where IP rights allowed you to get access to a research tool you would not have had otherwise?
  - o Yes, please specify
  - o No

e) In which of the following ways have IPRs benefited you/ your institution/ your program?

	Researcher	Institution	Program
• money incentives (profit)	cdn $	cdn$	cdn $
• recognition			
• ownership			
• trading chip			
• source of financing for your research			
• other, please specify			

Follow up questions

1. How is your program affected by what's happening worldwide in IP?
2. What are your strategies to limit the adverse effects of the changing IP regime (e.g. invent around, re-design the construct, ignore all IP (under the guise of research exemption), create public databases, challenge patents in court, go offshore, etc.)
3. Identify generally cases in which projects were stopped because of the inability to obtain the necessary property rights
4. Does the current system make the best use of germplasm (knowledge)?
5. In your view where is the Canadian breeding sector heading with IP?

Appendix B: Interview Consent Form

Interview Consent Form

You are invited to participate in a study entitled: ***Intellectual Property Rights and Plant Breeding in Canada***
Researcher: ________________________________ (name)
________________________________ (phone)

Purpose and procedure: We would like to receive your responses to some questions about the management of intellectual property at your institution and about the access to research tools from other organizations. By intellectual property (IP) we mean plant varieties, germplasm, cell lines, genes, process technologies and other property that is the result of one's intellectual efforts. Even though IP is intangible there exists a system of legal devices that prevents others from using IP and it is referred to as "intellectual property rights". Intellectual property rights can take a number of different forms. The most relevant for agriculture are patents, trade secrets and plant breeder's rights.

This research project is co-ordinated by the Department of Agricultural Economics (Dr. Gray and Dr. Fulton), University of Saskatchewan. The results of this research will constitute part of Ms. Viktoriya Galushko's thesis requirement for a PhD degree in Agricultural Economics, respectively. The research is funded by the Western Grain Research Foundation (WGRF) and the Canadian Innovation Research Network (CAIRN).

The purpose of the research is to explore how the application of property rights to intellectual property has changed over time, and to examine the impact of this change. This research will attempt to understand whether intellectual property rights (IPRs) are limiting access to the upstream innovations necessary for further research, and if so, whether these limitations are important in the Canadian canola/wheat breeding sector.

Your participation in this study is appreciated and completely voluntary. It is expected that the interview should last between 30 and 60 minutes. You may withdraw at any time without penalty during this process should you feel uncomfortable or at risk. All interviews will be audio taped and you have the right to shut off the tape recorder at any time if you choose. You should also feel free to decline to answer any particular question(s). Should you choose to withdraw from the study no data pertaining to your participation will be retained.

Potential risks: Ms. Galushko will make every effort to preserve the confidentiality of your comments (see below), but you should be aware that controversial remarks, in the unlikely event they are associated with you, could have negative consequences for your relationships with others in the canola/wheat breeding industry. Ms. Galushko will try to ensure that your identity is protected in the ways described below. If for some reason Ms. Galushko wish to quote you in some way that might reveal your identity, they will seek your permission beforehand.

Potential benefits: Your participation will help document the existence or absence of freedom to operate problems arising from the multiple research tools being protected by patents.

Findings from this research may help to make the Canadian plant breeding sector more responsive to the current economic needs and help to inform policy decisions within government.

Storage of Data: The transcripts and original audio recording of the interview will be securely stored by the Supervisors (Dr. Gray and Dr. Fulton) at the Department of Agricultural Economics for a period of five years.

Anonymous data will be aggregated with data gathered from other portions of this research.

Confidentiality: Your interview will be transcribed by Ms. Viktoriya Galushko or by a confidential secretary. After your interview, and prior to any data being included in a final report, you will be given the opportunity to review the transcript of your interview, and to add, alter, or delete information from the transcripts as you see fit. Interview transcripts will be seen only by Dr. Gray and Ms. Galushko.

The research conclusions will be published in a variety of formats, both print and electronic. These materials may be further used for purposes of conference presentations, or publication in academic journals, books or popular press. In these publications, the data will be reported in a manner that protects confidentiality and the anonymity of participants. Participants will be identified without names being used, giving minimal information if this information is relevant. Pseudonyms or composite profiles may be used to disguise identity further, if necessary. In principle, actual names will not be used; however, leaders whose position involves speaking on behalf of the organization may be asked if certain comments they have made can be attributed to them by name in publications. Any communication of these results that has clear potential to compromise your public anonymity will not proceed without your approval.

Right to Withdraw: You may withdraw from the study for any reason, at any time, without penalty of any sort. If you choose to withdraw from the study, any information that you have contributed will be deleted. You will be informed of any major changes that occur in the circumstances of this study or in the purpose and design of the research that may have a bearing on your decision to remain as a participant.

Questions: If you have any questions concerning the study, please feel free to contact the Researchers at the number provided above.

This study was approved on ethical grounds by the University of Saskatchewan Behavioural Sciences Research Ethics Board on October 13, 2006. Any questions regarding your rights as a participant may be addressed to that committee through the Office of Research Services (966-2084).

Consent to Participate: I have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw this consent at any time. A copy of this consent form has been given to me for my records.

__________________________ __________________
(Signature of Participant) (Date)

__________________________ __________________
(Signature of Researcher) (Date)

Appendix C: Interview Transcript Release Form

Interview Transcript Release Form

Intellectual Property Rights and Plant Breeding in Canada

I, __________________________________, have reviewed the complete transcript of my interview responses for this study, and have been provided with the opportunity to add, alter, and delete information from this transcript as appropriate. I hereby authorize the release of this transcript to the Department of Agricultural Economics, University of Saskatchewan, to be used in the manner described in the *Interview Consent Form (a)*, or the manner indicated below.

If you do not check one of the following, it will be assumed that (a) applies:

________ (a) I prefer to remain anonymous, as described in the consent form. I understand that my remarks will not be attributed to me by name. Instead, they may be attributed to an unnamed individual (a manager, a board member etc.) or to a pseudonym or a composite profile.

________ (b) The remarks contained in the authorized transcript may be attributed to me by name, or used anonymously, at the author's discretion.

________ (c) I prefer to have all remarks from the authorized transcript attributed to me by name if they are used.

________ (d) Certain remarks I have indicated by initials in the margin are to be kept anonymous as in (a) above; the rest of my comments (unmarked in the margins) may be attributed to me.

I have received a copy of this *Interview Transcript Release Form* for my own records.

_________________________ _________________________
Participant Date

_________________________ _________________________
Researcher Date

Viktoriya Galushko
Graduate Student, Department of Agricultural Economics
University of Saskatchewan
306.966-4032
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Appendix D: AAFRD Material Transfer Agreement

AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

FIELD CROP DEVELOPMENT CENTRE

Germplasm Transfer Agreement

Germplasm distributed by Alberta Agriculture, Food & Rural Development (AAFRD) falls into one of two categories:
(1) Designated ("In-Trust") Germplasm held by AAFRD for use in its research and
(2) Germplasm and cultivars developed by AAFRD

Germplasm and cultivars developed by Alberta Agriculture, Food & Rural Development (AAFRD), Field Crop Development Centre (FCDC) are the property of the FCDC and can be used only by authorization of the FCDC.

The material contained herein is furnished by AAFRD, Field Crop Development Centre under the following conditions:

1 AAFRD is making the material described in the attached list available as part of its policy of maximizing the utilization of genetic material for research. The material developed by AAFRD is made freely available for any agricultural research or breeding purposes, including reproduction of seed and/or transfer of germplasm to other parties, provided that the recipient accepts the conditions of this agreement.

2 Receipients are free to release for commercialization AAFRD research products in the form they are provided. Prior to the application for any form of intellectual property rights (IPR) on this germplasm or related information, written permission must be obtained from AAFRD. If it is released without obtaining IPR, AAFRD requests notification and acknowledgement. Moreover, while AAFRD recognizes the validity of IPR, it reserves the right to distribute all material in accordance with paragraph (1) above.

3 AAFRD makes no warranties as to the safety or title of the material, nor as to the accuracy or correctness of any passport or other data provided with the material. Neither does it make any warranties as to the quality, viability, or purity (genetic or mechanical) of the material being furnished. The phytosanitary condition of the material is warranted only as described in the attached phytosanitary certificate. The recipient assumes full responsibility for complying with the recipient nation's biosafety regulations and rules as to import or release of genetic material.

4 Upon request, AAFRD will furnish information that may be available in addition to whatever is furnished with the seed. Recipients are requested to furnish AAFRD with performance data collected during evaluations.

5 The material is supplied expressly conditional on acceptance of the terms of this Agreement. The recipients' retention and planting of the material constitutes acceptance.

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