FREEDOM TO OPERATE

AND CANOLA BREEDING IN CANADA

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ABSTRACT

Oikonomou, Emmanouil, M.Sc. University of Saskatchewan, Saskatoon, January 2008. Freedom to Operate and Canola Breeding in Canada.

Supervisor: Dr. Murray E. Fulton

The Canadian canola breeding sector met a transition from publicly funded breeding research to large private investments in research and development (R&D). The increasing use of biotechnology tools in the mid 1990s made the assignment of plant ownership technically possible while the legislative safeguards that were put in place during the same period enabled owners to take juristic actions against potential infringers. Today, canola breeding sector is dominated by large multinational firms. The generation of proprietary knowledge in the canola breeding sector has caused a freedom to operate issue. Private and public firms conducting canola R&D are seriously concerned about their ability to gain and preserve access to key technologies in an IPR world.

This thesis uses the tragedy of the anticommons framework to analyze the consequences of increased intellectual property protection in the canola breeding sector. Theory suggests that when a common resource is owned by multiple owners, each of the owners has the incentive to overcharge potential users, leading to the underuse of the resource. In R&D, different owners of complementary technologies may overcharge potential R&D firms that want to assemble different technological pieces to produce a new one. The result is forgoing research and development of new products.

The results of personal interviews with eleven canola researchers and IP officers are presented and analyzed. The results suggest that the increase in the intellectual property protection in the last two decades in the canola breeding sector has led to difficulties with canola R&D. These difficulties take the form of reduced access to current, proprietary and public material. With hampered access to research input material, research output is not maximized and potential research may be forgone. Interviewees described how the increase in the intellectual property protection affects their personal and organization's ability to conduct research as well as some the

implications of the new IP regime on the canola breeding sector. There is indication that canola breeding sector is moving towards a super-protectionism. Under these conditions, canola R&D firms, private and public, are in search for ways that will open access to enabling technologies and research areas. The creation of platform technologies and collaborations are the most prominent ones and are observed to increase in occurrence world wide.

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AAFC	Agriculture and Agri-Food Canada
CR4	Concentration Ratio for the top 4 companies
DNA	Deoxyribonucleic Acid
FTO	Freedom to Operate
HT	Herbicide Tolerant
IP	Intellectual Property
IPP	Intellectual Property Protection
IPR	Intellectual Property Right
MTA	Material Transfer Agreement
NRC	National Research Council
PBR	Plant Breeder's Right
PBRA	Plant Breeder's Right Act
PPA	Plant Patent Act
PVPA	Plant Variety Protection Act
RAC	Rapeseed Association of Canada
R&D	Research and Development
UPOV	International Union for the Protection of new Varieties of Plants
WTA	Willingness to Accept
WTP	Willingness to Pay

CHAPTER 1: INTRODUCTION

1.1. Background Information

Research in Canadian agriculture had its origins in the agricultural colleges established throughout Canada during the second half of the 19th century (Wallace, 1948). Agriculture was introduced into the schools of Upper Canada as early as 1847 and has continued to play a part in the curricula of schools and universities from that date until present (Wallace, 1948). While the work conducted at these schools was useful, it was inadequate to cover the need for agricultural research (The Canadian Encyclopedia, 2007). In 1886 Parliament passed a bill establishing five experimental farms (The Canadian Encyclopedia, 2007). Over time research centres were established throughout Canada, conducting research and contributing to the development of the agri-food industry (The Canadian Encyclopedia, 2007). A century and a half after the foundation of the first agricultural college, Canada had agricultural schools and universities in the provinces of Nova Scotia, Quebec, Ontario, Manitoba, Alberta, British Columbia and Saskatchewan (Wallace, 1948) as well as a network of research centers that were strategically placed in almost every province (The Canadian Encyclopedia, 2007) .

The public funding of agriculture research and development emerged due to the public good nature of innovation. Prior to the mid 1980s, there were no technical and institutional means that would effectively assign ownership of new plant varieties to the developers. The result was the well known free rider problem. Private firms had no incentives to undertake agricultural R&D since they had no way to collect revenue on the varieties that they developed. Given the inability of the market to motivate private involvement in agricultural R&D, the public sector's intervention was required. The establishment of public institutions such as the Canadian Department of Agriculture (now known as Agriculture and Agri-Food Canada (AAFC)) and the National Research

Center (NRC), as well as a number of universities, enabled a systematic production of innovation and new knowledge that added value to the agriculture sector.

A good example of the impact that innovation has on agriculture is the development of canola. Canola, originally rapeseed, is an oilseed that grows in cool climates such as those of Canada, Poland and Germany. In Canada, canola is grown in the provinces of Saskatchewan, Manitoba, Alberta, British Columbia, Quebec and Ontario. Rapeseed bears two characteristics that render it unsuitable for human consumption and animal feeding: the first one is its high erucic acid and the second one is its high glucosinolate content. Extensive research in rapeseed enabled the breeding of new rapeseed varieties with low levels of erucic acid and glucosinolates thereby making it suitable for human consumption and animal feeding. Today, canola is a major source of edible oil for many countries including Canada.

The history of canola industry has another key feature that makes it distinct and interesting; it has experienced two quite different property right regimes, one with relatively high freedom to operate and one with strong intellectual property rights (IPRs). During the first of the two regimes the canola industry was developed as a result of efforts undertaken by public organizations such as Agriculture Canada, NRC and the Rapeseed Association of Canada (RAC) (Gray et al., 2001). The breeding of new varieties with low erucic acid (2% or less) and low glucosinolate content (30 μmol/g or less) that transformed rapeseed to an oil suitable for human consumption and animal feeding was a result of the public sector's initiative and endeavour (Gray et al., 2001). At the breeding level, knowledge and germplasm were moved among scientists relatively freely (Gray et al., 2001). Trading among breeders was implemented informally and saved breeders from paperwork and tedious negotiations.

The advances in biotechnology and the introduction of intellectual property rights (IPRs) brought about many changes in the canola industry starting in the 1980s. During that period, a series of enactments that protected propagating material, such as the Patent Act and Plant Breeder's Rights (PBRs) took place. Newly developed genes could now be protected by the law and, through that, the whole plant containing these genes could be protected. As well, advances in biotechnology allowed varieties to be identified by their genetic make-up. These two developments meant that the means were now in place to allow firms to identify ownership and protect intellectual products. The result was that private firms begun to invest in R&D. Competition among R&D firms dictated an aggressive behavior towards patenting of research material. The canola industry evolved to its current form where a few large multinational companies dominate the sector and are the major force in the development of new varieties and products.

A comparison of the two regimes in the canola industry offers an excellent opportunity to examine the impact of changes in the way that information and new technologies are exchanged under different technological and ownership conditions. More specifically, the following questions can be asked: Has the introduction and use of IPRs affected breeders' access to research tools/germplasm? Do breeders have freedom to operate? Is there sharing going on among breeders?

1.2. Problem Statement

The assignment of IPRs is based on the rationale of providing incentives to private actors to undertake R&D by allowing them to temporarily capture the monopoly profits accruing from the commercialization of the inventions. By bestowing the innovative firm with ownership of its intellectual products, IPRs deter possible intellectual theft, thus making the recoupment of the cost possible. At the same time, by setting a finite time period for the duration of the IPRs, the benefits accruing from the innovation will be diffused to society through competition.

During the period of intellectual property protection, however, IPRs have been hypothesized (and in some cases observed) to have an adverse impact on the researcher's ability to build upon the work of others (see Shapiro (2001), Heller and Eisenberg (1998), Leger, (2007)). A researcher's freedom to operate and conduct research is threatened by the proprietary nature of the produced knowledge. The increasing volume of issued patents, PBRs and other means of intellectual protection has placed researchers on alert in order not to infringe IPRs that cover part of or aspects of their invention. Moreover, the owner of an innovation may be unwilling to share or license the product under protection.

Even if the technology can be shared, access to proprietary knowledge by third parties often requires the payment of a royalty fee to its owner. When the amount requested is more than the researcher/R&D firm can afford, further innovation may not take place. This holds particularly true when the creation of a new technology requires the use of a number of different technological pieces. The gathering of different technologies is costly and may never be realized because each owner has an incentive to overcharge on the permission to use the protected technology (Buchanan and Yoon, 2000).

The difficulties encountered by researchers in accessing knowledge have led economists to examine the freedom to operate issue. Pardey et al. (2003) examine freedom to operate in agriculture biotechnology in the developing countries. Nottenburg, Pardey and Wright address the issue of non-profit organizations' freedom to operate, while Menon studies the access to and transfer of genetic resources. Lastly, Sederoff and Meagher look into the possible constraints to R&D caused by blocked access to biotechnology.

1.3. Objective of the Study

The main objective of this thesis is to examine the freedom to operate among plant breeders in the canola industry in Western Canada. More specifically, the thesis examines the degree to which IPRs held by R&D private and public firms in agriculture is making it difficult for plant breeders to carry out their research.

The objectives of this thesis are:

- to examine canola breeders' access to current, public and proprietary research material;
- to investigate the current flow of knowledge among canola breeders and among organizations conducting canola R&D;
- to examine collaborations in canola R&D and their impact on research; and
- to improve our understanding regarding IPRs and the way(s) they affect research in the canola sector.

1.4. Methodology

To carry out the above objectives, a survey of people involved in canola R&D was employed. Twelve scientists and IP officers involved in canola breeding in and around Saskatoon were interviewed and surveyed.

The survey consisted of five parts. In the first part, interviewees provided descriptive data such as the area of breeding (traditional, biotech or both) they were engaged in, the number of research tools they have invented and the distribution of their funding among basic, applied research and development. The second part of the survey asked questions about the extent to which inventions in canola breeding are protected by intellectual property rights and the reasons that lead breeders/organizations to select particular types of protection. In part three, information regarding contracts and collaborative activity was collected, including questions regarding the impact that collaborations have on research programs and interviewee's intellectual property protection activity. The fourth part of the questionnaire collected data on the interviewees' freedom to operate, including the ability/inability to obtain the necessary research tools and their willingness to share their inventions with other canola breeders. The fifth part of the questionnaire dealt with the costs and benefits of having stronger IPRs. The survey also added a number of open-ended questions regarding the strategies used by the canola breeders or their organizations to limit the adverse effects of IPRs and whether the current IP system makes the best use of knowledge.

1.5. Thesis organization

The remaining chapters of the thesis are organized as follows. Chapter 2 provides a description of the crop research and plant breeding environment from 1940, when the first applications for rapeseed appeared, until today. During this period the canola industry underwent a number of structural changes, moving from a relatively minor crop to one of the major crops in the country. Chapter 3 sets out the methodology used for the study and outlines the details of the survey. Chapter 4 presents the theoretical structures used to explain and interpret the research findings. The theory deploys the tragedy of the anticommons theory (Heller and Eisenberg, 1998) and the pyramid framework (Shapiro, 2001) to illustrate how property rights can potentially constrain downstream research.

Chapter 5 analyzes both quantitative and qualitative data obtained from the survey using the theoretical building blocks presented in chapter 4. It focuses mainly on the negative impact of IPRs on research activity. Chapter 6 examines the implications of the findings on IPRs and freedom to operate. Lastly, Chapter 7 summarizes the findings and concludes the thesis.

CHAPTER 2: OVERVIEW OF THE INSTITUTIONAL CHANGES IN CANOLA RESEARCH

2.1. Introduction

Many economists maintain that insightful analysis of economic growth cannot be conducted using only the two traditional factors of production, capital and labour (Schumpeter, 1954, Grossman and Helpman, 1991). Contemporary economic prosperity in particular has been observed to depend increasingly on the creation and circulation of knowledge. The transformation of rapeseed to canola and the development of the canola market is an especially illustrative example of how the systematic production and exploitation of knowledge can lead to economic growth (see Phillips and Khachatourians, 2001). This chapter, then, describes how a crop that initially had a number of undesirable quality properties has become an international multi-billion dollar business.

2.2. The canola research environment, 1940-1985

A number of different factors provided an initial boost to canola production in the early 1940s. First, the Second World War created a need for oil used to lubricate marine steam engines, and rapeseed oil had been found to be the best lubricant available because it could cling to water and steam-wasted metal surfaces (White, 1974). Second, for much of the war, trade routes between Europe and Canada were broken or insecure, limiting rapeseed oil supplies from Europe to Canada. Thus, during the war the demand for rapeseed oil remained high. After the war, farmers in Western Canada sought to diversify their crop production (at that time they were limited mostly to growing wheat and barley) (Khachatourians *et al.,* 2001), and so a rather favourable economic environment existed for developing Canada's rapeseed industry.

Despite wartime demands, rapeseed was not yet a major oilseed crop. Its application was still limited to industrial uses, and even at that its future seemed limited.

After the war, demand decreased as more efficient combustion engines replaced steam engines, and petroleum products, whose supplies were once again more accessible, competed against rapeseed lubricants (Malla, 1996). The only way for rapeseed to become a viable economic endeavour was to extend its use. Investment however was required to develop new uses.

For the private sector, economic incentives were both small and obscure. In the post-war period, there were no quantifiable returns for canola research and development, and such uncertainty made it unattractive to private investment (Phillips and Khachatourians, 2001). Furthermore, a lack of legal protection for intellectual property rights that would secure the capture of economic rents by the owners deterred private sector involvement in the canola research industry. The only significant role that private companies played was in the area of oil processing, with minor participation from Edible Oils Ltd, the Saskatchewan Wheat Pool, and Canada Packers (Gray et al., 2001). All but by default, this left the impetus on the public sector to develop the industry.

The public sector dominated canola research in the period 1944-1984. The vast majority of research funding came from the public sector, particularly between 1944 and 1973 (see Table 2.1). New varieties were developed virtually exclusively by public institutions (Table 2.2) and were made freely available to the public.

Table 2.1. Investment in Canadian canola research by funding source and over selected periods.

Investment by	1944-1966	1967-1973	1974-1989	1990-1998
Millions CAN$ 1998				
Public sector	85	80	58	39
Private sector	15	17	40	59
Associations	0	2.5	2.2	2

Source: Phillips and Khachatourians, 2001.

Table 2.2. Canola varieties developed by institution.

Years	1940-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995	1996	1997
Number of varieties developed									
Public institutions	4	6	8	6	10	12	2	4	2
Private companies	0	0	0	0	9	32	18	28	29
Total all institutions	4	6	8	6	19	44	20	32	31
Market share by institution									
Public institutions	100%	100%	99.8%	99%	98%	49%	27%	26%	11%
Private companies	0%	0%	0.2%	0.7%	0.4%	43%	57%	61%	63%

Source: Phillips and Khachatoutians, 2001 (market shares do not add up to 100% due to the share of the acreage not being reported to specific varieties; private market share is probably underreported as a result).

The involvement of the Canadian government in canola research activity came about, in part, due to a perception that development of an edible oil source was a matter of national security (National Research Council, 1992). The main obstacle related to the suitability of rapeseed oil for edible purposes was the high content in rapeseed oil of erucic acid (20%-55%) which was believed to have adverse effects on human health when consumed.

Studies recognizing the adverse impacts of rapeseed oil consumption date back to 1956, when K.K. Caroll, Department of Medical Research, University of Western Ontario, found links to reduced weight gain, fatty heart, increased cholesterol, and increased weight of adrenal glands in rats (Sauer and Kramer, 1983). This and other health studies forced canola breeders to change their focus from the agronomic traits of rapeseed to the development of a variety with low erucic acid. This need to shift research focus was affirmed at the International Rapeseed Conference in 1970, where a group of European scientists presented a study indicating that high erucic rapeseed oil consumption by young animals caused a short-term fat build-up around the heart and kidneys that appeared to cause long-term muscle lesions in the heart (Gray et al., 2001).

The necessity for pushing canola research in a specific direction of development was obvious, but it lacked a central institution that could organize, fund, and direct such an effort. There was no actor whose interests were large enough to undertake such a venture independently. Farmers, processors, and handlers had small interests individually, but collectively they were not organized well to fuel and shape development of the canola sector (Gray et al., 2001). These groups found their voice through the Rapeseed Association of Canada (RAC), which was established in 1967.

RAC partnered with other public institutions in this period, such as Agriculture Canada, the National Research Council (NRC), and universities. By 1968, this effort had resulted in the development of the first low erucic *B. napus* variety by Drs. Downey (Agriculture and Agri-food Canada) and Steffansson (University of Manitoba). Agriculture Canada and RAC continued their efforts, and by 1974 ninety-five percent of the changeover to low erucic varieties was complete (NRC, 1992).

The second major drawback that rapeseed had was the presence of glucosinolates in the seed. Once the oil was extracted, the meal component that was left over contained glucosinolates. In the mid 1950s, it was found proof of high correlation between glucosinolate concentration and thyroid disorders (NRC, 1992). At about the same time, other research showed that glucosinolate compounds also affected the general well-being of the animal (NRC, 1992). In 1967, seeds from plants of the Bronowski variety (*B. napus*) were found to be low in glucosinolates. This genetic source for low glucosinolates content was then utilized to develop low erucic, low glucosinolate varieties (Canola Council of Canada, 2005). In 1974, University of Manitoba registered Tower, the first *B. napus* variety with both low erucic acid and low glucosinolates. In the following years two more "double low" varieties were registered, Candle (*B. rapa*) and Regent. Once rapeseed varieties with low erucic acid and glucosinolates had been bred and after further research on dropping erucic acid and glucosinolate content levels had been carried out, the Rapeseed Association registered the name 'canola' for rapeseed varieties with 2% or less erucic acid and 30 μmol or less glucosinolates (Gray et al., 2001).

The research environment was vital to this breakthrough. Researchers from public institutions freely exchanged ideas, knowledge, germplasm, and other inventions related to the breeding sector (Phillips and Khachatourians, 2001). Ongoing projects were openly discussed and collaborations evolved through mutual interest to achieve a specific outcome. The public character of the research provided breeders with a common goal: the development of canola varieties that would benefit Canadian society.

2.3. Legislation activity since the 1980s

After a quarter-century of dominance in rapeseed research and developing the canola market, public sector involvement reached its peak in the 1990s. Cutbacks in public funding during the 1990s and the large investments required for research and development in canola restricted further public sector influence (Gray et al., 2001).

Concurrent with this funding shift, a biotechnology revolution was underway and its impact on plant breeding was promising. Biotechnology innovations significantly reduced the time needed to develop new canola varieties. Advances in breeding techniques and new research tools also made breeding programs more cost effective. More importantly, biotechnology opened the way for the application of intellectual property protection in plant breeding, as it provided scientists with the tools to identify ownership of the seeds. These changes made the canola industry more appealing to private investors. The final piece that private companies needed before entering the marketplace was a means of protecting their investment from intellectual theft.

Prior to the 1990s, legal protection of plant varieties was relatively weak. In Canada, the Seeds Act of 1923 required that only registered varieties could be sold (Kuyek, 2004). New varieties could only be registered if they satisfied certain quality standards (Kuyek, 2004). The provisions of the act were designed to validate the identity of a new variety and determine its suitability for seed certification (CFIA, 2005). However, it did not provide protection to the owner of a new seed from possible infringers.

In the United States, the only forms of protection at that time were the Plant Patent Act (PPA) and the Plant Variety Protection Act (PVPA), enacted in 1930 and 1970 respectively. The PPA provides for a "plant patent" and is limited only to asexually produced plant varieties, while the PVPA provides for a certificate of plant variety protection only to sexually reproduced plant varieties. Even though the two acts provide some form of varietal protection, they contain certain deficiencies compared to utility patents. The description requirements for plant patents are less rigourous than those of utility patents, and unlike utility patents PVPA certificates cannot exclude all commercial uses of the protected variety (Kjeldgaard and Marsh, 1994). Utility patents fulfill these conditions, but are not applicable to plants. Hence, there was a need for a more consistent and coherent form of protection for plant varieties. This, however, did not come to pass until 1985, when the Patent and Trademark Office's Board of Appeals and Interferences' case of *Ex Parte Hibberd* (227 U.S.P.Q 433 [P.T.O Bd. App. And Inter. 1985]) allowed for the patenting of artificially modified plants, both in the traditional manner as well as through biotechnological plant breeding.

In Canada, unlike the United States, the patenting of higher life forms (i.e., plants and animals) is prohibited. However, the Canadian Patent Act of 1985 allows the granting of patents for research material such as modified genes, gene sequences, promoters, or plant cells, which can be used as a means of controlling the entire plant (as found in *Monsanto Canada Inc. v. Schmeiser,* 2004). The granting of patents to biological organisms and genes was established by the 1982 decision of the Commissioner of Patents who ruled that claims made by Abitibi Co for a yeast culture and by Connaught Laboratories for a cell culture were patentable (Duy, 2001).

Responding to the lack of an alternative form of intellectual protection that would be both plant specific and provide protection to new varieties, the Canadian government passed the Plant Breeder's Rights Act (PBRA) in 1990. The PBRA grants exclusive rights to the holder of a plant variety, and allows the holder to sell or produce for sale propagating material of the plant variety and make use of it to produce another plant variety for commercial purposes. PBRs leave the door open for researchers to use freely this material for research purposes and for farmers to keep propagating material as a seed source for subsequent seasons. These two implicit exemptions, known as "breeder's exemption" and "farmers' privilege," distinguish PBRs from patents, rendering the former a weaker form of protection (Forge, 2005). Nevertheless, PBRs are widely used in Canada, particularly by the private sector, providing an additional option for varietal protection.

Another form of intellectual property rights for plants is the International Convention for the Protection of New Varieties of Plants, established in 1961 by the International Union for the Protection of New Varieties of Plants (UPOV). Since that initial effort, there have been a number of amendments, the most notable coming in 1978 and 1991. Canada acceded to UPOV in 1992, but still needs to bring the PBRA in agreement with the Convention for ratification. The aim of the Convention is to recognize and ensure the breeder of a new plant variety the right to protect it either by granting a special title of protection or patent. Unlike the PBRA, the UPOV in its most recent form explicitly allows exceptions to "acts for experimental purposes" (article 15 (1)), but limits farmers' privilege by making it an optional exception (Forge, 2005).

The series of IPR enactments offered potential for private investments in the canola sector in the 1990s. Seed companies could file canola varieties with new traits and agrochemical firms could patent modified genes resistant to certain herbicides (e.g., Monsanto's Round-up Ready®). The assignment of intellectual property rights to private developers was one of the two main factors that encouraged private investors to enter the canola industry. The other one was the development and application of biotechnology in canola breeding.

2.4. The period 1985-2007

Breakthroughs in biotechnology and its application to several crops, including canola, brought about major changes in agriculture. More specifically, the emergence of transgenic plants—plants with foreign genes introduced to provide enhanced traits—have eased the plant breeding process and enabled the insertion of desirable characteristics both for the benefit of producers and consumers.

The first method for transferring genes into plants was discovered by Horsch *et al.* in 1985 who successfully transformed and regenerated petunia, tobacco and tomato plants. A key feature of the method used was a soil bacterium, *Agrobacterium tumefaciens*, the action of which enabled the transfer of genetic material to plants (Davey 1989). The application of this revolutionary method to canola occurred for the first time in 1987 by Fry *et al.,* who produced the first transformed *Brassica napus* plant. After this event the development of transgenic canola seeds took off. Multinational private firms such as Monsanto and Bayer saw commercial value in the production of transgenic seeds resistant to certain herbicides such as glyphosate and glufosinate. Monsanto developed Round Up Ready® canola, a variety resistant to glyphosate while Bayer developed Liberty®, which is resistant to glufosinate (Keller, 2007). The first field tests for Round Up Ready® and Liberty® took place in 1988 and 1990 while the varieties were registered in 1996 and 1995 correspondingly (Keller, 2007).

In addition to the transgenic HT variaties Round Up Ready® and Liberty®, Clearfield®, a third type of HT variety was developed in 1995. Clearfield® is resistant to imidazolinone herbicide which is used to control weeds in several crops including wheat, maize, rice, oilseed rape and others (USDA, 2007). In contrast to Round Up Ready® and Liberty® varieties which are transgenics, Clearfield® was developed using mutagenesis and selection (USDA, 2007). These three HT varieties consist the bulk of canola varieties grown in Canada today.

The benefits to farmers resulting from the development of herbicide resistant canola varieties were many. To begin with, Round Up® Ready and Liberty® are nonselective herbicides meaning that a wide spectrum of weed can be managed (University of Nebraska, 2002). Such broad spectrum control is particularly important in no-till systems and weedy fields (University of Nebraska, 2002). Secondly, the introduction of herbicide tolerant (HT) crops resulted in a price reduction for conventional herbicides (University of Nebraska, 2002). The price reduction is the result of the market adjustment and an attempt by companies to remain competitive with herbicides used on non-herbicide tolerant crops (University of Nebraska, 2002). In general, glyphosate and glufosinate have lower toxicity to humans and animals compared to some other herbicides (University of Nebraska, 2002). Since they are readily absorbed by the organic particles in the soil and decompose rapidly, they pose little danger due to leaching and contamination of ground water or toxicity to wildlife (University of Nebraska, 2002).

The above benefits of HT varieties motivated farmers to rapidly adopt the new seeds. Figure 2.1 illustrates the increased use of HT technology that took place in Canada for canola during the period 1995-2005.

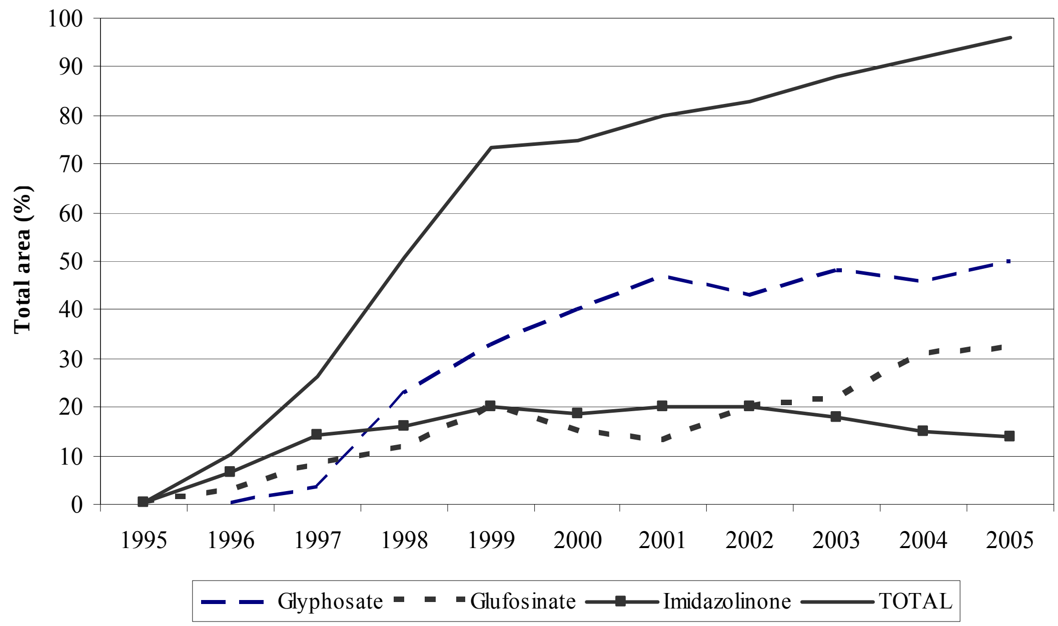

Figure 2.1. Percentage usage of herbicide tolerant (HT) Brassica napus canola in Canada (1995 – 2005).

Source: W. Keller, 2007.

As figure 2.1 shows, during the early years of HT technology there was a steep increase in its use by the farmers. By 1999, four years after the introduction of HT to the market, HT canola accounted for more than 70% of the total canola acreage. By 2005 HT canola dominated production with 95% of total acreage.

Another technological breakthrough that has affected the production of canola is the use of hybrid technology for the production of hybrid canola varieties. A canola hybrid is the result of crossbreeding two lines of canola (Canola Council of Canada, 2005). When crossing two parents there is a possibility to obtain an offspring with enhanced characteristics (also known as hybrid vigour or heterosis). In canola, hybrid varieties are produced using controlled breeding such as cutoplasmic male sterility (CMS), plant genetic system (PGS) and synthetics. The resulting hybrid varieties from these processes have shown increased yields of up to 15-20% (Keller, 2007).

Another characteristic of hybrid seeds is that they do not maintain their genetic composition for the next year, making it very costly for farmers to keep the seed. This characteristic is important for the company developing the seed since they are assured a demand for seed every year. In the last five to six years, hybrid varieties have been rapidly adopted by canola growers. Figure 2.2 illustrates the adoption of hybrid varieties at the expense of the open-pollinated varieties.

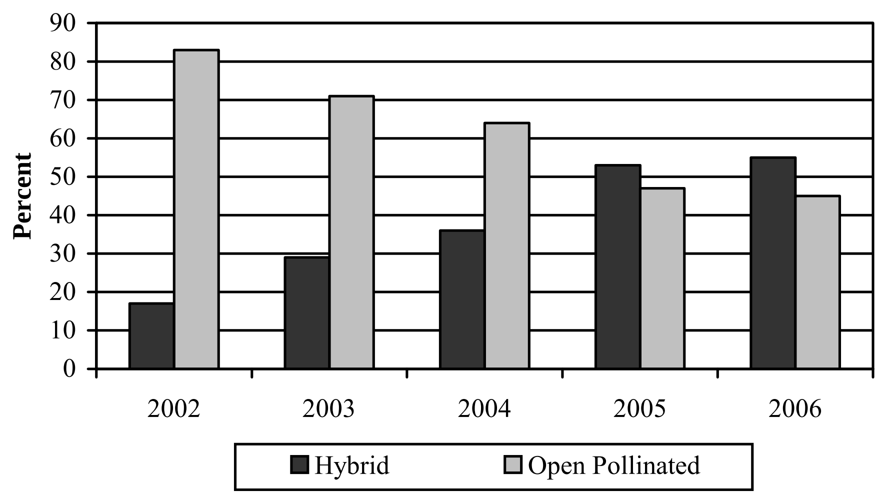

Figure 2.2. Rate of Hybrid Adoption in Canada.

Source: Canola Council of Canada.

In recent years, the application of genomics in plant breeding has occurred. Genomics is the study of the complete sequence of DNA, including all of the genes, of an organism (NRC, 2007). In plant breeding, genomics provide the opportunity to intervene on the plant germplasm and modify targeted characteristics with greater precision and rapidity (Baima, 2005). Current efforts from research institutions such as Genome Canada focus on the generation of various genomic resources (e.g. microarrays, ESTs, markers) that help to identify a large number of new genes (Keller, 2007). The identification of a plant's genes is critical, since they control important functions and characteristics such as seed vigor, plant architecture, seed composition and oil content (Keller, 2007). The introduction of new characteristics in a plant affects its economic, nutritional and health value.

Genomics are increasingly being used in canola breeding. In Canada, the federal government has initiated genomics research within federal labs such as the Genomics and Health Initiative (GHI) in NRC and the Crop Genomics Initiative (CGI) in AAFC. Investments in these two initiatives are approximately $50 million Canadian (Keller, 2007). NRC and AAFC have recently submitted a joint collection of 597,000 *Brassica napus* ESTs which represents nearly 90% of all submitted Brassica ESTs (NRC, 2007). ESTs provide researcher with a view of the "functional" parts of a genome where gene expression takes place (NRC, 2007). By using ESTs to study how genes are expressed within canola, it is then possible to manipulate these genes in order to enrich canola with desirable traits (NRC, 2007). According to Keller (2007), the commercialization of new traits will be more prominent after 2015, as the current stage is confined to the development of prototypes.

The application of new biotechnology processes to canola and the new IP regime in plants, gave rise to large private investments. Concurrent with a decline in public R&D, the result was that by the late 1990s, private companies accounted for almost half the developed varieties and half the independent breeding programs producing at least one commercial variety (Table 2.3). Large and often vertically integrated multinationals managed a large portion of the supply chain and controlled a series of productive activities (e.g., seed industry, production of herbicides). This required a strong and solid base to enable large research and development investments that might yield improved or differentiated end products. These research and development initiatives have resulted in scientific breakthroughs that have contributed to the advancement of the sector. Many involved in the industry agree that such investments would never have been undertaken by the public sector, nor would the resulting technological improvements have been achieved.

In addition to consolidation, private sector firms are also engaging in large-scale collaborations. In March 2007, Monsanto and BASF announced a long-term joint R&D project worth $1.5 billion to examine the development of high yielding crops and crops that are more tolerant to environmental stresses such as droughts (Food Navigator, 2007). A second example is a Monsanto-Dow collaboration for the development of SmartStax™ corn. The new variety will incorporate eight different herbicide tolerance and insect-protection genes from both companies (Food Navigator, 2007). The venture supposes that both firms will cross license under royalty agreements linked to their insect protection systems and weed control systems (Food Navigator, 2007). The value of these cross-licenses is in the billions of dollars.

Table 2.3. Independent breeding programs producing at least one commercial variety per year.

	B. napus		*B. rapa*	
	Private	Public	Private	Public
1950-1959	0	1	0	1
1960-1969	0	2	0	2
1970-1979	0	2	0	1
1980-1984	0	3	0	1
1985-1989	5	4	2	1
1990-1994	13	3	3	3
1995-1998	14	3	3	1

Source: Phillips and Khachatourians, 2001.

On the other hand, increased private research and development activity has generated greater proprietary knowledge. As innovations take place in private laboratories, entrepreneurs want to ensure that their intellectual products are protected.

The generation of proprietary knowledge, however, is still something relatively new to the canola sector. The transition from a regime where publicly bred varieties were freely distributed to farmers to one where large multinationals make heavy investments in research and development and appropriate its products implies a whole series of changes in the market structure (e.g., mergers, takeovers), supply chain, firm organization and behavior, the public sector's role, and the way that scientific research and application is conducted.

The focus of this study is an examination of the impact of increased proprietary knowledge on plant breeding. The questions that this study will address include: Do canola breeders have access to vital research material under the new regime of IPRs? Does the existence of multiple IP owners may block the gathering of dispersed IP pieces, thereby limiting development?

CHAPTER 3: THEORETICAL FRAMEWORK

3.1. Introduction

In plant breeding, as in other R&D industries, knowledge is both an input and an output (Shapiro, 2001). Breeders use various research tools to breed new varieties, discover new traits or invent advanced research tools. When plant breeding takes place in an IP free environment where access to inputs is costless, the two roles of knowledge do not conflict with one another. Available research output can be freely used by other scientists for further research. When knowledge becomes proprietary, research output is still produced or enhanced; however, its proprietary nature may hinder it from being used as an input. The research and development of new products may require the use of various research tools owned by different research organizations. In many instances, these technologies are not available to researchers either because the owners have decided not to share/trade or because there are costs associated with their acquirement. The purpose of this chapter is to examine the implications of proprietary knowledge in canola R&D in the light of its dual role as an input and output.

The chapter begins with a classification of goods as public, private, toll or common pool. This distinction is useful in understanding why IPR legislation was introduced in the 1980s and what that introduction has meant for plant breeding. The IP regime change has both a positive and negative effect on the generation of knowledge. The positive effect is well known and easy to observe: research effort has increased due to the private sector's involvement. The negative effect is not so obvious; we need to be aware of the special feature of knowledge as both an input and output. The two effects are then incorporated into a single analysis that views the overall impact of IPRs on R&D and offers inferences regarding the desirable IPR regime.

3.2. The nature of goods

Each good possesses certain characteristics regarding its use. Economists have singled out two characteristics, excludability and rivalry, as being of particular significance for the manner in which goods are produced.

Samuelson (1954) categorized goods according to whether they are rival or non-rival. A rival good is one whose consumption by one person restricts the ability of others to consume that good (e.g., ice cream or shampoo). On the other hand, the use of non-rival goods by one person does not reduce their use by someone else. Examples of non-rival goods include swimming pools or knowledge of a technique in plant breeding.

Musgrave (1959) further classified goods as being excludable or non excludable. Excludability refers to situations where consumers can be excluded from the consumption of a good without incurring substantial cost. An example is a car for sale; the ownership of the car by the seller excludes people from using it. Conversely, non-excludable goods are those whose exclusion is either impossible or prohibitively costly and therefore everyone has the right to use them. For example, it would be very costly to try and restrict peoples' use of the air that they breathe-this is a non-excludable good.

Economists use rivalry and excludability as the defining characteristics of goods (see, for example, Romer, 1990). Applying these two criteria, the following four categories are derived.

Table 3.1. Classification of goods.

	Excludable	Non-excludable
Rival	Private goods	Common pool goods
Non-rival	Toll goods	Public goods

Source: Gray, Fulton and Furtan, 2007.

Private goods are both excludable and rival. The fact that these goods are excludable means that private ownership may occur. Toll goods are non-rival and excludable. A toll highway is an example of a toll good. Drivers can be excluded from the highway while, at least until the point of congestion, the drivers' use of the road does not affect another's use. Public goods are non-rival and non-excludable. Once they have been produced everyone can consume them and restricting other individuals from their use is costly. Traffic lights and signs are good examples of public goods.

Finally, common pool goods are rival but non-excludable. The governance and the procurement of this category of goods appear to be the most problematic. The reason is that while everybody has access to them (i.e. they are non-excludable), their use by one person reduces the amount available to others (i.e. they are rival), motivating users to utilize the good as much as possible. This phenomenon is known as the tragedy of the commons (Hardin, 1968), which, as it will be shown later, is strongly linked to the tragedy of the anticommons (Heller and Eisenberg, 1968; Buchanan and Yoon, 2000).

The preceding classifications are incomplete since there are many goods that possess a mixture of these attributes on different levels. The above summary, however, is a useful rough guide for understanding how the nature of goods changes when one or both of the above characteristics changes.

3.3. The nature of knowledge and its implications

3.3.1. Changing the nature of knowledge

The output in canola R&D, as in other R&D industries, is knowledge. In the absence of IP rights, knowledge is a non-excludable and non-rival good; once it is produced it is difficult to prevent others from using it and the use of this knowledge by no means reduces its availability to other scientists. Both characteristics pose problems in the production of the good by the private sector. Private firms supply goods and services, hoping that their disposition in the market will yield enough value to pay for the factors employed in their production. If the good or service can be consumed without any payment, private firms will make losses and eventually abandon their production. When the nature of the good renders profit unattainable, the market fails and other structures must be examined for the production of the good.

As we have seen in chapter 2, until the mid 1980s, canola R&D was carried out almost exclusively by public institutions (Gray, Fulton and Furtan, 2001). When public funding became inadequate to cover the increasing need for investments in the biotechnology industry, and when the government wanted to reduce its expenditures, private sector involvement was encouraged by the new opportunities offered by the development of biotechnology and the creation of IPRs. Biotechnology offered the tools with which the ownership of varieties could be determined. The assignment of IPRs and the creation of the legal means to penalize infringers made excludability possible. In plant breeding, the breeder of a variety with a new trait could avert its free use by patenting the genes responsible for the trait. In this way, scientific knowledge was transformed from a non-excludable good to an excludable good, while its non-rival characteristic was maintained. In the classification of goods context, R&D moved from being a public good to being a toll good.

The transformation of scientific knowledge from non-excludable to an excludable good had an impact on the horizontal structure of the agricultural R&D industry. According to Romer (1990), the use of non-rival goods as inputs in the production process creates increasing returns to scale. The reason is that a non-rival input can be used multiple times in the production process without costing the firm anything additional (Fulton, 1997). Correspondingly, in R&D, technological advancement is a non-rival input whose repeated use in the production process lowers average cost (Fulton, 1997). In order to cover the cost of the technological advancement that creates increasing returns to scale, the R&D firm must price its output above marginal cost (Fulton, 1997). This pricing behaviour can only be carried out if the industry contains a small number of firms and is non-competitive (Fulton, 1997).

Therefore, the transformation of knowledge to an excludable good that was enabled by the introduction of IPRs is a partial factor in the consolidation of the agrochemical, seed and biotech industries (Fulton and Giannakas, 2001). According to the World Development Report (WDR) 2008, in 1997 the market share for the four largest agrochemical and seed companies was 33% for agrochemicals and 23% for seeds while in 2004 the concentration ratio of the top four companies (CR4) increased to 60% and 33% respectively. With respect to biotechnology patents that were issued in the US, the CR4 was 38% in 2004 (WDR, 2008). Generally, it is believed that when an industry's CR4 is greater than 40% the market competitiveness starts to decline (WDR, 2008). The consolidation that is observed in the chemical and seed markets cannot be attributed exclusively to the transformation of knowledge from a non-excludable to an excludable good, but is due to other factors as well, such as escalation strategies.

The presence of increasing returns to scale in the production process also causes the hold-up problem (Fulton, 1997). The hold-up problem appears when one party is reluctant to make an investment because of the fear of opportunistic behavior (Fulton, 1997). This opportunistic behavior may take the form of an increase in the price of an input. The increase in price may be facilitated by the market power held by the few firms in the input market. For example, suppose there is an agrochemical company that plans to initiate R&D to discover a gene that is resistant to one of its chemical products. The insertion of that gene into a crop, e.g. canola, will render that crop resistant to the company's chemical. The company's plan is to purchase seed from a seed company, insert the gene into the seed and then sell to farmers both the chemical and the seed resistant to it, recouping the costs for R&D. However, if the seed industry is concentrated enough, once the investments for the gene have been made by the agrochemical company, seed companies will raise the price of the seed to extract the maximum possible rent from the agrochemical company. If the agrochemical company knows that seed companies will follow this strategy, it will choose not to invest in the new trait in the first place. In this way, research efforts may be forgone and research opportunities are lost. To avoid the hold-up problem, the agrochemical companies could decide to purchase the seed company. In other words, when IPRs create opportunities for exploitation, a possible remedy is the integration of upstream or downstream companies (Fulton and Giannakas, 2001). Therefore, vertical integration through mergers and acquisitions is another explanation of the agricultural industry's observed consolidation.

As many economists have recognized, knowledge plays a dual role – it is both an output and an input (Shapiro, 2001). The privatization of scientific knowledge has undoubtedly increased its output; at the same time, this privatization has created an array of proprietary technologies. A problem emerges when these proprietary technologies cannot be used as inputs for further research, perhaps because of factors such as high royalties or unwillingness to license. Restricted access to inputs (i.e. new technologies) is expected to result in reduced output. The following section explains how this happens and shows why the dual role of knowledge becomes of utmost importance when R&D is carried out under IP protection.

3.3.2. The pyramid framework

Scientific research and technological development (namely R&D) involve the creation, usage and application of knowledge for the commercialization of material or immaterial products (Investor Words, 2007). The dual role of knowledge as an input and output in scientific research has permitted the gradual *building* of science as we experience it today. The history of science is full of examples where previous technological achievements were employed as the foundation of new ones. The dynamic character of this process can be pictured as the construction of a pyramid (Shapiro, 2001). In the same way that bricks are placed on top of others to create a pyramid, new knowledge is based on previous findings. This knowledge is in turn used by scientists to make new inventions. As long as there are no restrictions in using the previous building blocks, the pyramid will continue to grow.

The introduction of property rights in the generation of knowledge may impede the above process. The owners of intellectual property can place a restriction on the use of their intellectual products or ask for a royalty. If the potential developer of a new technology is not granted access to key inputs or technologies, the assembly of the pyramid will be problematic. Some of its segments will never be realized or they will be developed with a time lag. The damage becomes more severe when the proprietary knowledge lies at the bottom of the structure, with the lack of access to enabling technologies blocking a wide range of technological breakthroughs. Thus, the assignment of intellectual property rights has the potential to affect both the shape of the pyramid and the time horizon of its composition.

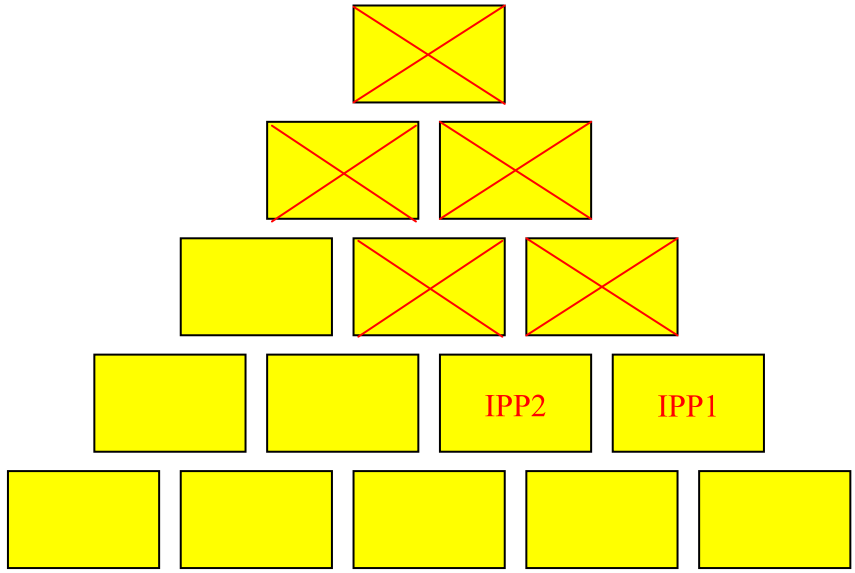

Figure 3.1. The Pyramid with Intellectual Property Protection.

Figure 3.1 depicts the building of science. Each building block represents a technology, an invention or other types of knowledge. The higher rows of blocks represent newer technology while the lower blocks represent older and more fundamental knowledge. Building blocks of the same row are typically complement technologies; both building blocks are needed for the creation of the piece above them.

Suppose that two of the building blocks are proprietary, IPP1 and IPP2; in the case of plant breeding they are technologies protected by patents or PBRs. Also, assume that the two technologies are owned by different owners. The ownership of the technologies gives owners the right to exclude third parties from their use. If the right is used, third parties will not be able to conduct R&D and to create the next building blocks and consequently all the subsequent ones, shown as being crossed out, will never be realized. The refusal of one of the owners to license/share the technology is both a necessary and sufficient condition to lead to this outcome. As we move towards the top of the pyramid, more access has to be obtained, as dependence from previous building blocks increases. Therefore, the existence of multiple proprietary building blocks may hinder the building of the pyramid, causing difficulties for future R&D.

3.3.3. Plant Breeding in the Pyramid framework

Before fitting the plant breeding case into the pyramid framework, there is a need to distinguish between current and completed research materials. Current material refers to material under development or research projects that are on their way to being completed. Access to ongoing research is critical as it can broaden or improve a research project. Completed material refers to the outcome of completed research. Completed material can be further classified as proprietary or public. Proprietary material is protected by IPRs, for example PBRs and patents. Public material refers to publicly available sources; anyone can have access without cost (other than a citation). R&D organizations may choose not to protect their invention for various reasons: the invention may not be subject to patenting, the costs of filing may be too high relative to its value or the material may not be commercially exploitable. In addition, universities and public institutions may release to the public the results of their R&D.

Plant breeding science is cumulative; therefore it is well suited to the pyramid metaphor. The building may take the form of a resistant gene transplanted in a high protein content seed yielding a new variety, or the combination of quality germplasm for varietal breeding of novel traits. New research tools like double haploids and tissue cultures speed up the breeding process reducing the time needed for the development of new varieties. Access to the three types of material, proprietary, public and current, is captured by the pyramid framework as well; the first two in an obvious way. Current material can also be represented by a building block upon which future research can be built. Current research plays a prominent role in R&D as in many cases its results are used in the innovation process. Lack of access to all three types of materials retards the advancement of science and the building of the pyramid.

The preceding analysis shows how knowledge is created and that when knowledge becomes proprietary and blockage to intellectual property rights occurs, subsequent innovation remains unexploited. Privatization of knowledge is a reality today, but blockage to intellectual property rights may or may not happen depending on the owners' incentives. The tragedy of the commons and anticommons examine the incentives of right owners to make use of their rights and the outcomes of this choice.

3.4. The tragedy of the commons and anticommons

The conventional problem of the commons (Hardin, 1968) is well understood by economists (see the discussion in section 3.2). In this situation, there is a common resource whose rights of use are spread among multiple users. If the resource is scarce, usage by one user will have negative external effects on the rest of the uses because his or her use of the resource will reduce the amount available to others. The end result—the depletion of the resource—is what is known as the tragedy of the commons.

The common fisheries example is frequently used to describe the tragedy of the commons. Suppose there is a fishing lake where everybody has the right to fish as much quantity as he/she wants. If the total quantity fished is smaller than the population growth, the resource will be sustained. If, however, the total quantity fished is greater than the population growth, the resource will be driven to a low level (potentially zero). Which of the two conditions is more bound to happen? The tragedy of the commons framework suggests the latter and the reason lies in the incentives. There is both a benefit and a cost related to each caught fish. While the benefit is private in nature (the fish's value is reaped by its catcher), the cost is public (the potential offspring from the fish would have been available for everyone). Therefore, each individual has a strong incentive (which is the full benefit) but a weak disincentive (a fraction of the cost) to fish. The end result is the over catching of fish and their eventual depletion[1].

The tragedy of the anticommons (Heller and Eisenberg, 1998) can be viewed as the opposite problem.[2] In the anticommons set-up, there are, in addition to rights of use, assigned rights of exclusion. The holder of such a right is able to prevent others from using the resource. When exclusion rights are assigned to multiple owners, and the rights are complementary (i.e. all rights must be acquired for access to be granted), each

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[1] The tragedy of the commons is based on the assumption that the individuals are self interested and they will not act to achieve their common interest (Olson, 1965). However, recent theoretical and experimental work (e.g. see Runge, 1986) suggests the existence of multiple types of individuals, some more willing than others to initiate reciprocity to achieve the benefits of collective action (Ostrom, 2000). The formation of social norms such as reciprocity, trust and fairness may encourage collective action that will help managing common pool resources (Ostrom, 2000).

[2] Heller and Eisenberg (1998) have noted that anticommons property can best be understood as the mirror image of commons property. Buchanan and Yoon (2000) have further indicated that there is a symmetry between the commons and the anticommons problem.

owner can block the other owners from using the resource. The result is that it remains intact or only partly exploited. To better illustrate the tragedy of the anticommons, consider again the fisheries example. Suppose this time a number of people individually have been granted the right to exclude potential fishers. If one member of that group exercises his right to exclude everyone else from fishing, the fishing lake will remain unexploited. In other words, anybody wanting to fish will have to collect permissions from all right holders. This collection procedure ranges from being tedious to impossible. Furthermore, as the number of right holders increases, it becomes more complicated and costly to gather the required rights, increasing the value of the resource that remains unexploited (Buchanan and Yoon, 2000). Both parties, the right holders and the potential users reach a lose-lose solution as they have failed to coordinate their actions and come to some sort of an agreement that would allow them to take advantage of the resource. Of course, the fishing example is extreme. In reality only a portion of the resource is subject to exclusion rights.

Research and development provides an important real-life example of a situation where the tragedy of the anticommons can occur. In this paradigm, the common resource is R&D and the exclusive rights take the form of patents or other forms of intellectual protection. Each patent holder can potentially exclude other firms or researchers from utilizing the protected technology. The potential for a tragedy of the anticommons arises when the technologies under protection are complementary, meaning that multiple technological pieces are needed for the realization of a new one. If the assemblance of the different IP pieces is impossible or prohibitively costly, the new technology will never be realized, leaving unexploited a part of the research domain. In research areas where freedom to operate exists or institutions find ways (e.g. patent pools, consortiums) to put together all necessary IP pieces, the tragedy of the anticommons is avoided.

The tragedy of the anticommons may well be at work in plant breeding: patents and PBRs can potentially exclude breeders from using proprietary genes, germplasm and research tools, thus stifling research and putting barriers in place for subsequent innovation. Future innovation in some research areas may never be realized if the owner of the key technology is unwilling to license/share it, or if it is carried out at a slow pace.

The development of new varieties is a long run process (at least ten to fifteen years) and includes the use of different technologies in the form of improved research tools or newly identified genes. In many instances inaccessibility to one of these inputs is enough to cause the abandonment of the whole research project.

In the tragedy of anticommons, the inefficient management of a resource is due to external disturbances caused by the exercising of rights. The external disturbances take the form of blocked access to the resource. The externalities are negative in the sense that they bear some cost to the recipient, either by reducing the good's rents or preventing their capture.

So, how to exercise one's rights without hampering those of other owners? Coase (1960) provided one answer to this enigma, suggesting that rights become subjects of property. In this way, rights are traded among the interested parties, thereby internalizing the negative externalities. Theoretically the licensing of property rights should eliminate the tragedy of anticommons. Indeed, patents can be licensed for a royalty, allowing the licensee to use the acquired technology to his advantage.

However, this ideal situation presupposes that royalty fees are low enough to allow the innovating firm to capture some of the rents from the commercialization of the new technology. If the sum of the royalty fees the innovative firm is required to pay outmatch the future rents, the firm will not proceed to the innovation process. In other words, the total revenues accruing from the new technology must be equal or greater than the costs of its research plus the required royalty fees. This condition is difficult to be satisfied because (a) the decision for the size of the royalty fees is taken by independent institutions; and (b) the uncertain nature of profits.

In the first case, each IP owner will try to maximize the revenue from royalty fees but at the same time total royalty fees must be low enough to satisfy the following condition:

$$\text{(1)} \quad \text{total revenues} - \text{total costs} \geq \text{total royalty fees}$$

If the total revenues minus the costs are less than total royalty fees, the research will not be undertaken and all parties will lose. If the revenues minus the costs are greater than total royalty fees, it means that IP owners could ask for higher royalty fees. Rational and informed owners would set the royalty fees low enough for (1) to hold in equality. In this case IP owners extract the maximum amount of rents from the innovative firm, which, nonetheless undertakes the research (the factors of production are still paid). The problem arises when multiple IP owners make decisions independently about the height of royalty fees. If IP owners do not cooperate, which is a realistic scenario, condition (1) may not hold. The competition among IP owners to capture the rents created by the gathering of the two technologies, will lead to overcharging the third firm. If each firm tries to obtain the lions' share of the rents by setting its royalty fees high, the innovative firm will not undertake the research effort, resulting in an outcome similar to the fishery example. In both cases, the tragedy of the anticommons refers to the unused resource-the resources not used due to the inability to combine all the necessary property rights.

The second reason that condition (1) may not hold is the uncertainty over the research output and the revenues that it can confer. While the licensing fees and the costs can be recognized, the revenues are speculative. This means that in condition (1), each party (the innovative firm and the IP owners) expects a different value for total revenues. Diverse expectations will result in different charges for royalty fees, *ceteris paribus*. For instance, if an IP owner expects high total revenues, he will overprice his patent. If the expected total revenues are low, the licensing fee will be adjusted accordingly. In the unfortunate case where the expected total revenues by the innovative firm are less than those of IP owners, the innovative effort will not be undertaken.

The trade of new technologies may not occur for other reasons such as strategic behavior, the prospect for further development and patent races. Firms may strategically choose not to license to their competitors in order to drive them out of the market or to block entry to new firms (Yiannaka and Fulton, 2005). Some technologies have the potential for improvement, which is something that the innovator would like to take advantage of first. Lastly, competing firms may be engaged in a race for a patent (Loury 1979, Dasgupta and Stiglitz, 1980), therefore any disclosure to the rival firm would make his own research effort more difficult.

Another hurdle that hampers the trade of technologies is the so called "hold up" problem. Suppose R&D firms, in an effort to speed up the R&D process, exercise their research exemption and use foreign material in the plant breeding prior to acquiring IP rights. This places the IP owner in a strong bargaining position and the R&D firm in a weak one since the latter has already invested in the research, and perhaps the development, of a new product. The technology owner can use this power to extract the maximum rent from the R&D firm. Knowing that its potential rent will be extracted in this way affects the R&D firm's incentive to use the IP material in the first place. If the rent that is extracted is large enough, the R&D firm will not have sufficient revenue to cover the cost of its investment. Thus, it will decide not to undertake the investment in the first place. The result is a "hold-up" of the new technology that could otherwise have been developed.

The hold up problem becomes even worse when there are multiple IP owners, each of whom owns a separate technological building block. If the technological pieces are complementary and the owners cannot cooperate, then each of them will have both the incentive and the bargaining power to overcharge the firm that has made investments to put all the IP pieces together. If this scenario were to occur, the R&D firm would abandon its efforts and not undertake the investment in the first place. The outcome of the hold-up problem is the forgoing of the research and the loss of its value for the society.

As will be shown later in the thesis, R&D firms employ a number of strategies to obtain access to critical material. The presence of these strategies indicates that hold up is an issue that plant breeders have to deal with and that they are taking action to avoid being caught in a situation where they would lack bargaining power or be unable to use key technologies. Indeed, the interviews showed numerous instances where plant breeders were delayed because of the inability to secure a license.

Another important parameter is the existence of transactions costs. The handling of rights presupposes multiple transactions, some being quite complex, among owners and interested parties. Licensing for example, presupposes a search by the patent holder, the successful completion of the negotiation process and the implementation of the agreed conditions. Such transactions are not costless and are less likely to happen between competitive parties. Moreover, many public institutions (e.g., universities) have limited resources to cope with transaction costs and limited ability to bargain with other players (Heller and Eisenberg, 1998). In condition (1) explained above, transaction costs would be part of the total costs; as transaction costs rise, the possibility increases that total royalty fees exceed total revenues minus total costs. In other words, transaction costs add to the possibility that trade will not occur in IP.

There are other factors that can negatively influence transactions. For example, in the bargaining process over patent, researchers may be subject to cognitive biases (Heller and Eisenberg, 1998). According to Tversky and Kahneman (1991), the same difference between two options will be given greater weight if it is viewed as difference between two disadvantages than if it is viewed as a difference between two advantages (the so called *loss aversion*). For example, hockey fans are more enthusiastic when their team covers a handicap of -3 goals than when their team gets ahead +3 goals; they value the difference between two disadvantages (-3) more than the difference between two advantages (+3). In the same way, researchers/negotiators are less likely to reach an agreement when the attributes over which they bargain are framed as losses than when they are framed as gains (Bazerman and Carroll, 1987). This means that in the negotiation processes the concessions that one party makes (the losses) are evaluated more than the concessions offered by the other party (the gains). In transactions, that would mean that the involved parties show a smaller willingness to pay (WTP) and a higher willingness to accept (WTA) than their objective evaluations of the patent(s) at stake. Given that a transaction is carried out when WTP > WTA, cognitive biases decrease the feasible territory of transactions.

To get around the above barriers to IP access, private firms conducting R&D have developed alternative practices. Some of them are attainable only through collaboration among R&D enterprises (e.g., non-disclosure agreements, cross-licensing, patent pools, consortiums), while other involve a certain amount of risk (e.g., infringing, inventing around). However, even these means have certain drawbacks associated with them. For example, patent pools and cross licenses are limited by antitrust law (Shapiro, 2001). Furthermore, the formation of all the above structures presupposes negotiations and transactions, the cost of which is again burdening the budget of the involving parties.

As it is observed, transaction costs are present in most of the set-ups that try to deal with restricted access to proprietary knowledge. The next section deals with the transaction costs and their management.

3.5. Transaction costs

Under a classical analysis, economic agents are believed to undertake activities and decisions in a fully informed and rational manner. For example, in competitive markets, a buyer is supposed to be aware of all possible ranges of prices offered by different firms (known as "perfect knowledge") and rational enough to choose the most desirable option. It assumes that consumers are knowledgeable enough to trace different trade opportunities, pick the one to which both parties agree, and avoid those agents who fail to observe the rules of the trade. This kind of clarity and information, however, is either unattainable[3] or costly (in terms of money and time). Hence, transactions, the performance of which is indissolubly linked with knowledge of the market, contain what are known as "transaction costs."

Three kinds of transaction costs have been recognized: search costs (related to detecting individuals suitable for the transaction); negotiation costs (for coming to an arrangement under agreeable terms); and enforcement costs (those associated with supervising the observance of agreed upon rules) (Dahlman, 1979). All three costs emanate from insufficient information. Search costs arise because of limited information regarding candidate agents for a transaction. Negotiation and enforcement costs could be prevented or limited if there was adequate information about willingness to trade and maintain agreed upon conditions (Dahlman, 1979).

The identification of transaction costs and exploration of their attributes is essential in recognizing their appearance and importance in the markets. In R&D industries, transaction costs play a major role in the flow of proprietary knowledge.

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[3] The literature regarding an individual's limits in absorbing and retaining information refers to this as "bounded rationality" (Simon, 1995). Bounded rationality constrains individuals from adapting the optimum amount of information because the full range of possibilities is unknown (Simon, 1991). When an individual is confronted with excessive information, he/she will select that which best aligns with past experiences or knowledge base (Lang, 2006).

Given that knowledge is an input for these industries, transaction costs become a key aspect in understanding why knowledge may not be accessed when privatized.

3.6. Determining the optimum level of control: Incentives and Disincentives to R&D

So far, it has been shown that IPR legislation affects overall research activity in two opposing ways. On the positive side, IPRs help recoup research costs, thus providing incentives to innovators. On the negative side, as protective measures become more rigorous, further innovation that uses the protected technology is deterred due to the tragedy of the anticommons effect. These positive and negative impacts can be considered as incentives and disincentives for further research. Given the incentives and disincentives to R&D, the overall impact of IPRs on R&D can be examined. The exploration of these two impacts allows for inferences to be made regarding the level of IPR that maximizes net R&D output. These inferences can then be used in policy making, particularly policies that target the maximization of net R&D output.

The likely incentive relationship between IPRs and R&D is suggested by the work of Akerlof et al. (2003). Akerlof et al. (2003) argue that stronger copyrights do not always endow inventors with substantially greater incentives to innovate. According to their calculations, the additional incentive from the extension of copyright in new works is much less than one percent. This suggests that, at least in the case of copyright, there is a critical point after which additional strengthening of IPRs (extension of copyrights in Akerlof *et al.'s* case) induces a very small amount of new works. With this background, the relationship between IPR strength and IPR induced R&D can be expected to have the form drawn in figure 3.2.

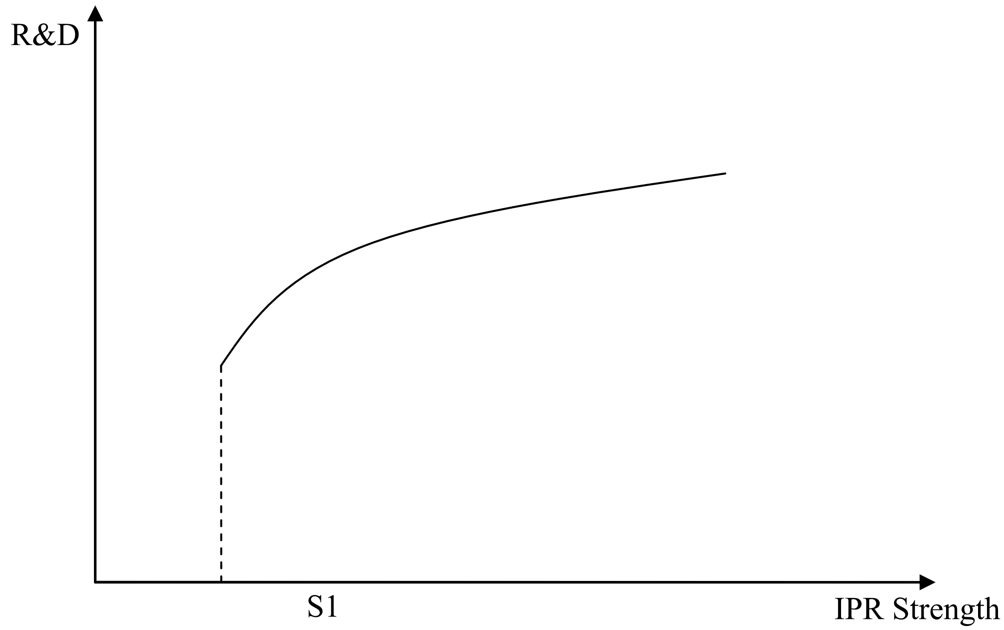

Figure 3.2. Incentives from IPRs.

Figure 3.2 illustrates that an increase in the strength of IPRs leads to an increase in R&D activity, albeit at a reduced rate. Thus, as IPRs become stronger the impact in R&D activity becomes less and less. As in most other activities, there is diminishing marginal return to increased IPR strength. IPR strength S1 is the point after which additional strengthening of IPRs (e.g., a term extension or a widening of scope) increases R&D at a diminishing rate. For IPR strength less than S1, it is expected that diminishing returns have not yet set in. The exact shape of the curve prior to S1 is of minor importance because society will never wish to operate in this region – society will always choose an IPR strength at least as large as S1.

To determine the level of IPRs that maximizes R&D activity, the shapes of the curves showing both the incentives and the disincentives to R&D are required. In contrast to the incentive curve, the disincentive curve is expected to rise at an increasing rate. Enhanced IPRs make the effort and costs of patenting worthwhile, even for research tools whose current value is not so high but whose future value may be large. The generation of patents in the pyramid framework would mean that more building blocks would be owned by IP owners. As the number of proprietary building blocks increases, the likelihood of blockage increases. Likewise, as the number of patents rises, the tragedy of the anticommons is expected to occur more often and become more severe. So, as it is shown in figure 3.3, the disincentives of IPRs are expected to rise at an increasing rate.

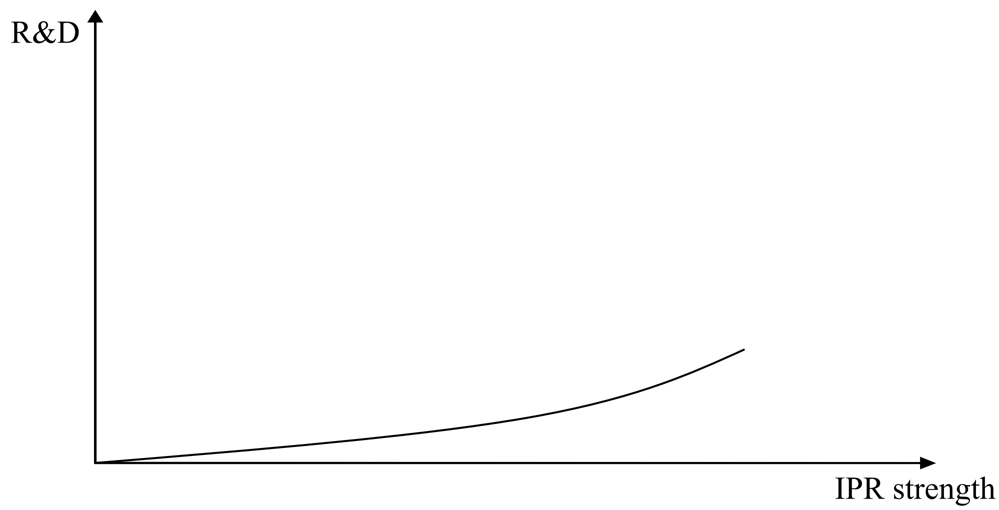

Figure 3.3. Disincentives from IPRs.

Once the shape of the incentive and the disincentive curves have been determined, IPRs' overall impact on R&D can be examined by incorporating both curves into a single analysis. The exact form and position of the incentive and the disincentive firms are unknown; therefore two broad cases can be distinguished, the interior and the corner solution. In both cases it is assumed that the negative impact of IPRs on R&D is always less than the corresponding positive impact, so that there is a net benefit to having some degree of IPRs. Diagrammatically, the presence of net benefits to IPRs means that the disincentives curve always lies under the incentives curve.

3.6.1. Interior Solution

The objective is to find the level of IPR strength that maximizes the net gain in R&D output. The net gain in terms of R&D is determined by the vertical difference between the incentives curve and the disincentives curve. The net gains in R&D are maximized at the IPR strength where the slope of the incentives curve equals the slope of the disincentives curve. The slope of the two curves at a point is given by their tangents at that point. In figure 3.4 this occurs at point S* where the two tangents, curves I and II, are parallel.

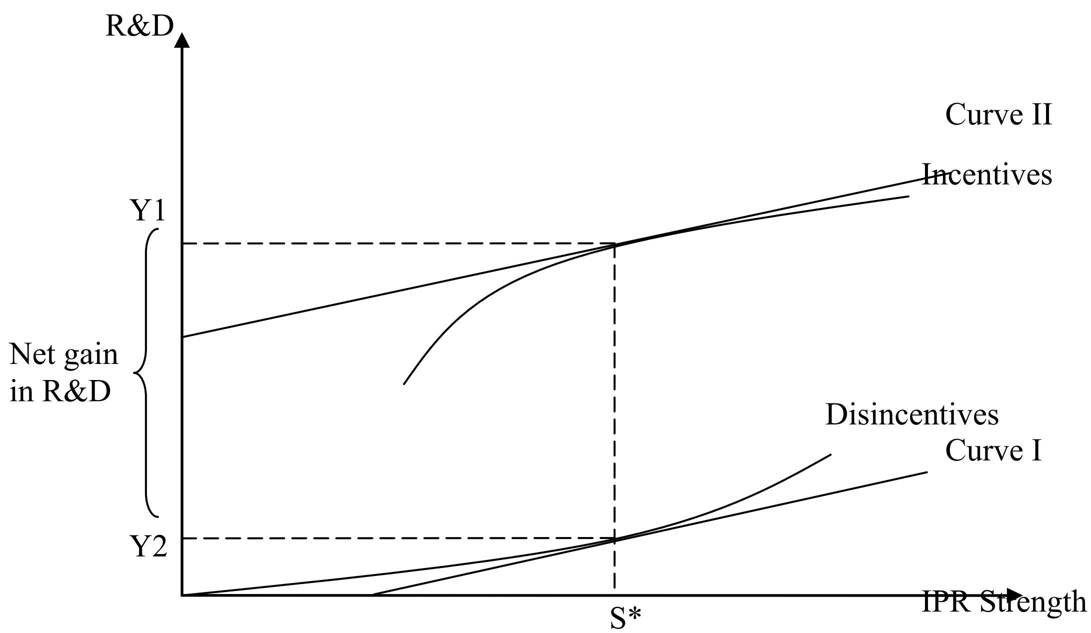

Figure 3.4. Maximum R&D output.

3.6.2. Corner Solutions

In the analysis shown in Figure 3.4, S* lies between the two possible extreme situations: one where there are no IPRs and the other where IPRs are at their maximum strength. In figure 3.5 these levels are marked as Smin and Smax, respectively. Smin refers to a situation where IPRs are completely absent; anyone can use anyone else's intellectual products without paying a price for them. This environment bears many similarities to the canola industry prior to the 1980s where intellectual products could not be technically identified and protected. At Smin, both the incentives and the disincentives are expected to be minimal; the incentives are low because of the free rider problem and the disincentives are low because no permissions need to be acquired. At the other extreme, Smax is a regime with very powerful intellectual property rights both in terms of patent duration (e.g. infinite number of years) and patent scope. Strong IPRs endow

R&D firms that own or have access to key technologies with substantial negotiation power.

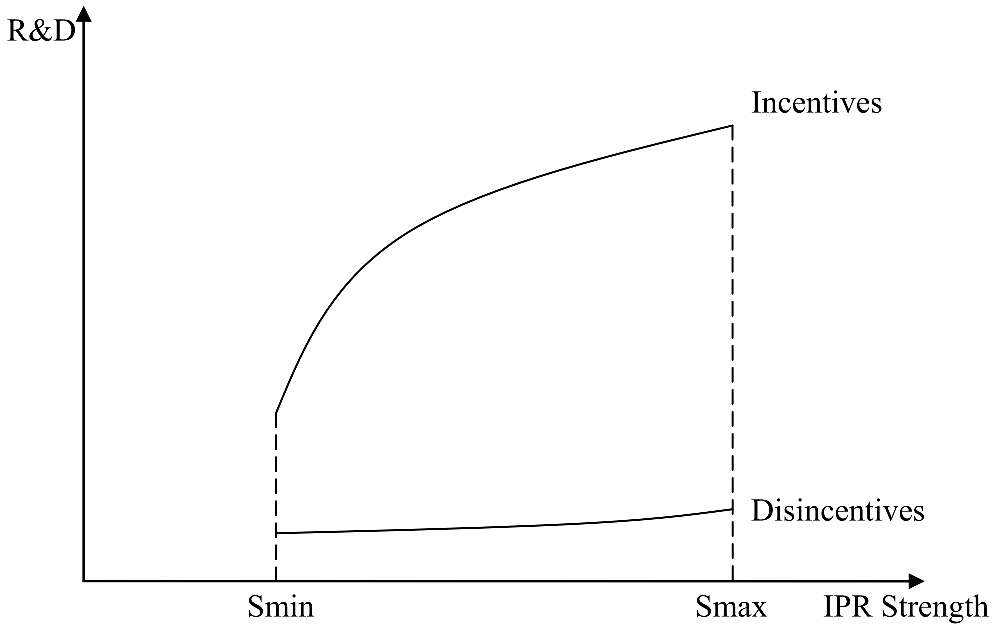

Figure 3.5. Conditions in which maximum IPR strength is optimum.

The corner solution examines the conditions under which the optimum value of the control variable, in our case IPR strength, coincides with the maximum or minimum value of this variable.

In figure 3.5 the incentive and the disincentive curves are drawn so that at maximum IPR strength (Smax) the slope of the incentive curve is larger than that of the disincentive curve. In this case, the vertical distance between the incentive and the disincentive curves is maximized at Smax. In contrast to the interior solution where the optimum IPR strength requires a modest/balanced IPR strength, in this corner solution the optimum for society in terms of R&D output is to extend patents as much as possible e.g. by increasing patent duration for a large number of years. Therefore, even though the tragedy of the anticommons is at work (as IPR strength increases, the disincentives for R&D increase) maximum IPR strength is nevertheless the optimum solution in maximizing net R&D gains. This is so because while increasing IPR strength has a negative effect on R&D, the positive effect on R&D is even larger. The marginal gains in R&D from IPRs outweigh the marginal losses caused by the tragedy of the anticommons effect, rendering additional IPR extension desirable.

The case where the net gains in R&D are maximized at the minimum IPR strength is also possible. This scenario emerges when at Smin the slope of the disincentive curve is larger than that of the incentive curve (this case is not illustrated). If at Smin the marginal benefit from increasing IPR strength is less than the marginal cost, then the net gains in R&D are maximized at this point.

From the above it is evident that the relative magnitudes of the positive and negative effects play a crucial role in determining the appropriate level of R&D strength. As well, even though the tragedy of the anticommons is at work, further IPR extension may still be beneficial in some cases.

3.7. Summary

The alteration of knowledge from a non-excludable good to an excludable good that was enabled by advances in biotechnology and IPR legislation in Canada has changed knowledge's availability to the research community. Given that advancement in science requires the use of knowledge generated by multiple and different research entities, the assignment of IPRs may encumber research enhancement. IPRs have made knowledge proprietary, endowing owners with the right to exclude possible users. The prospect of blockage becomes more likely when permission from multiple owners is required for the creation of a new technology. When cooperation among IP owners is impossible, each owner has an incentive to overcharge the prospective licensor. The end result can be the abandonment of the research effort.

The tragedy of the anticommons theory identifies a way in which IPRs may discourage further research. When both the incentives and the incentives resulting from IPRs are incorporated into the analysis, valuable inferences can be made regarding the desirable IPR regime. As the interior and corner solutions indicate, the optimum IPR strength critically depends on the position and shape of the incentive and the disincentive curves.

CHAPTER 4: METHODOLOGY

4.1. Introduction

Data for this thesis was collected by in-person interviews. During the interview, respondents were asked short closed-ended questions and broader open-ended questions. The key for a successful empirical study is the presence of several safeguards that enhance the consistency of the data collected and that eliminate subjective elements in the analysis. The discussion of the survey is followed by a brief description of the database set up and the implementation of the interview processes. This chapter concludes with additional information on the selection process for the interviewees and the participation rate.

4.2. Survey research

Survey research is a fundamental tool for measurement in applied social research. Survey research includes any measurement procedures that involve asking questions of respondents (Trochim, 2006). Surveys can be divided in two categories: the questionnaire and the interview. Each of these methods has several types according to their implementation. For instance, interviews may be personal or conducted by telephone. Likewise, there are group administered questionnaires, household drop-off surveys and mail surveys (Trochim, 2006). Each of these types has some advantages and disadvantages. For example, personal interviews allow for direct contact with the respondent but they are time consuming. For the purpose of this thesis, personal interviews were used. During the interviews, the respondents were asked very specific questions from which quantitative data could be obtained. Qualitative data were also collected when the respondent elaborated on the specific questions and when they addressed the more open-ended questions. The combination of both qualitative and quantitative data allowed for data collection that would not be able to capture by using only one of the two methods.

4.3. Quality characteristics of an empirical study

The quality of any empirical social research is commonly checked on four bases: construct validity; internal validity; external validity; and reliability. Construct validity seeks agreement between a theoretical concept and a specific measuring device or procedure (Trochim, 2006). Construct validity is increased through the use of multiple sources of evidence (e.g., documentation, interviews, archival records), the establishment of a chain of evidence, and feedback on the draft from key informants (Yin, 2003, p. 36). This thesis uses diverse inputs such as interviews, published documents, theses, and survey data in an effort to ensure construct validity.

Internal validity refers to an investigator's ability to make inferences based on interview and documentary evidence collected as part of the research (Yin, 2003). Pattern matching, explanation building, addressing rival explanations, and using logic models are techniques for ensuring internal validity. Pattern matching logic compares an empirically based pattern with a predicted one, while explanation building, a special type of pattern building, aims at analyzing data by building an explanation about the case (Trochim, 1989, p. 120). Logic models are another form of pattern matching. Their distinguishing feature is that they stipulate a complex chain of events over time (Trochim, 1989, p. 127). Finally, rival explanations in empirical studies must be exposed and further evidence examined that either supports or disproves the original hypothesis.

External validity involves the extent to which the results of a study can be generalized beyond the sample (Bracht and Glass, 1968). In other words, it indicates whether the results of the study can be applied to other people (population validity) or settings (ecological validity) (Bracht and Glass, 1968). There are two threats to external validity, population validity and ecological validity. Population Validity refers to the extent to which the results of a study can be generalized from the specific sample that was studied to a larger group of subjects, while Ecological Validity the extent to which the results of an experiment can be generalized from the set of environmental conditions created by the researcher to other environmental conditions (Bracht and Glass, 1968).

Reliability is the consistency of the measurement, or the degree to which an instrument measures the same way each time it is used under the same condition with the same subjects (Gall et al., 1996). In other words it is the repeatability of your measurement. A measure is considered reliable if a person's score on the same test given twice is similar (Gall et al., 1996).

4.4. Survey database

Interviews were the principal source of data for building a formal database. Participants were either scientists involved in canola breeding or IP officers. As a result, not every interview followed the same set of questions. IP officers mainly offered data related to the cost of IP services, while canola breeders provided data on IP protection of their research outcomes. The data were aggregated and organized into two electronic files—a Microsoft Excel spreadsheet containing the answers and their frequencies, and a Microsoft Word document, which divided responses into coding themes such as secrecy, licensing, collaboration, and sharing. Accords, arguments, and quotes were arranged either in support or in opposition to each theme. The spreadsheet was used to make tables and plot graphs, while the Word document served as the basis for the qualitative analysis.

4.5. Canola interviews

A key source of information for the thesis is the interviews with canola breeders and others involved in canola breeding. The interviews had a dual purpose: (1) to collect data concerning canola breeding and intellectual property protection that could be used for current and future research; and (2) to provide canola scientists an opportunity to express possible concerns and personal views regarding the current IP regime and its impact (if any) on their individual research effort and on canola research and development in general. The questions were carefully constructed to avoid possible misunderstandings and misinterpretations by interviewees.[4] When necessary, questions were followed by definitions of crucial terms (e.g., research tool), terms with multiple or

[44] The contribution of C.J. Pozniak, professor in the Crop Development Centre, University of Saskatchewan, and wheat breeder, was invaluable in pre-testing the questionnaire and selecting the technical terms in the wording of the questions.

wide interpretations (e.g., secrecy), or economic terms (e.g., transaction costs). Further clarifications were provided during the interview process.

The questionnaire was designed to elicit data and information closely related to the subject under study, but without requiring participants to reveal proprietary information. For example, scientists were asked to describe any research tools that they had invented, but the aim was a general reference to the kinds of tools used (e.g., markers, gene sequences) rather than a technical description of the invention. This was intended to put interviewees at ease.

Prior to conducting the interviews, approval was secured from the University of Saskatchewan's Behavioural Ethics Committee. Approval of the study's procedures for data collection, storage, and use, as well as guidelines for respecting interviewees' anonymity, was granted on September 20, 2006.

4.5.1. Interview process

All potential interviewees were initially contacted via e-mail. This gave the researcher an opportunity to introduce himself, briefly present interviewees with the purpose and scope of the research, and then explain the importance of their participation to the project. Once interviewees expressed their willingness to take part, a mutually convenient date for conducting an interview was established. The questionnaire (see Appendix A), the interview consent form, and, in most cases, the interview transcript release form were sent two to three days prior to the appointment. Permitting potential interviewees an opportunity to take a look at the questionnaire before the interview allowed them to make an informed decision as to whether they desired to participate. It also provided them with a sense of context and helped them better understand the information being sought. Such advance familiarization made the discussion more fluid and focused on issues relevant to the research. The consent form was included to elaborate more on the purpose of the interviews, the procedure, and the potential benefits and risks, as well as confidentiality issues. Recognizing the sensitivity of some questions, interviewees were encouraged to express any concerns about the above.[5]

Most interviews lasted between forty-five and sixty minutes, and all but one were audio recorded (due to technical difficulties with the recorder one interview was not recorded). For the one interview that was not recorded, the data from the questionnaire were included in the formal database with the interviewee's consent. However, the qualitative data from the interview could not be used. Transcription generally took seven to eight hours per interview. Some were transcribed twice or more to obtain the highest possible degree of accuracy. Transcripts were then forwarded by e-mail to the interviewees for revision, correction, and clarification. Interviewees were encouraged to change an answer, clarify arguments, or provide further explanations wherever necessary. Edited transcripts were returned along with a signed Interview Transcript Release Form (Appendix C).

The Interview Transcript Release Form offered a range of confidentiality status options for interviewees. In all but one cases, the interviewees chose to remain anonymous. Hence, in the analysis section they are referred to as "breeders", "researchers", "scientists" etc. Whenever applicable, responses are attributed to a group of people, such as "a number of breeders recognized that …" or "some scientists alleged ….". All interviewees have been assigned two numbers. When a quote from an interview is used to support or reject an argument, it is referenced by one of the two numbers that have been assigned to him. In doing so, the possibility that an interviewee may be recognized by his/her quotes is minimized. The preservation of participants' anonymity was crucial, for it allowed them to express freely their personal views and thoughts even as they revealed sensitive information.

4.5.2. Selection of potential interviewees

In a search for the most appropriate interviewees to provide information relative to the research question, two factors were taken into account: the potential interviewee's

[5] For example, in question 29, interviewees were asked to reveal the percentage of cases in which they used patented material without a license. Question 30 asked for incidents where they developed a new research tool/variety without first obtaining freedom-to-operate.

involvement in either canola breeding[6] or intellectual protection management.[7] A list of forty names was compiled, mainly by reviewing potential interviewees' research interests and their research profile according to their institution's website. The choice of institutions was based on their involvement in canola research and development. Particular weight was given to obtain a significant representation from both the public and the private sectors. Consultation with Dr. Murray Fulton (thesis supervisor) narrowed the list to approximately twenty-five potential interviewees. Final selection was based on Dr. Fulton's insight into potential interviewees' experience in canola breeding. Dr. Wilf Keller (thesis committee member) was also invited to review the list and propose additions or deletions. Dr. Keller has been actively involved in the development and application of biotechnologies for the genetic modification of crops, particularly canola. He has collaborated with numerous government, university, and industry groups, and has provided training for researchers in plant biotechnology. Thus, his experience and knowledge of the canola research community were valuable inputs for the formation of the list. Taking into account these suggestions, the final list consisted of twenty-two potential participants—seventeen involved in canola breeding and five in IP management. Only the thesis advisor and the researcher know which individuals were eventually interviewed.

4.5.3. Participation rate

Thirteen personal interviews were carried out with canola breeders, developers of research tools, and IP officers (Dr. Fulton participated in six of them). The acceptance rate of interview requests was sixty-eight percent. Three potential interviewees were not contacted due to a lack of up-to-date contact information. Of the remaining nineteen interviewees, three declined immediately, three felt it inappropriate to participate, and thirteen accepted and completed the interviews. From those completing the interviews,

[6] For the purposes of this thesis, the scientists involved in plant breeding can be divided in two categories: breeders and non-breeders. The former develop new canola varieties, while the latter produce tools (markers, vectors) used in canola breeding. In the search for interviewees, both types of scientists were sought.
[7] Of particular interest were officers managing IP protection on new plant varieties. Their inclusion in the sample was fortunate as they filled in different parts of the picture.

12 agreed to have the transcripts released in the thesis. One interviewee refused to sign the interview transcript release form and therefore the qualitative-quantitative data from this person were not included.

The applicability of the questions varied and resulted in different answer rates for some questions. For example, IP officers responded only to part five (related to the costs and benefits of stronger IP) of the questionnaire and to the follow-up questions. Likewise, scientists not developing canola varieties skipped questions related to that topic.

CHAPTER 5: DATA PRESENTATION

5.1. Introduction

It is well established that strong intellectual property rights increase R&D and innovative activity. As Chapter 2 has shown, this has certainly been the experience in the canola industry. As the previous chapter showed, however, there is also an argument that stronger IPRs may restrict further R&D. The purpose of this chapter is to use data collected from interviews with canola breeders to examine the impact that IP protection is having on R&D activity in this sector.

The chapter starts off by recognizing a key characteristic of contemporary R&D: the elevation of intellectual property protection activity. The increased IP protection is then argued to block breeders' access to public, current and proprietary material. The following sections provide evidence that this is happening in the canola industry. The analysis in this chapter is based on 12 interviews, 8 with canola researchers and 4 with IP officers. The interviews with the canola breeders provided qualitative and quantitative data while the interviews with IP officers provided qualitative data only.

5.2. Profile of canola breeders/researchers

Table 5.1 presents data on the number of years the respondents have been involved in canola breeding. The eight canola breeders that were interviewed have been involved in canola breeding for a considerable amount of time, the minimum being 10 years and the maximum being 34 years. Some of them have also been involved in the breeding of other plants (e.g., wheat, flax) at one point in their career. The significant experience of the respondents means that they are familiar with IP issues in the industry. Indeed, some scientists have been involved with breeding long enough to experience the transition from a regime with no IP protection to one with strong IP safeguards.

Table 5.1. Number of years the respondents were involved in canola breeding.

Number of years	Frequency	Percent
1-4	0	0
5-8	0	0
9-12	3	37.5
13-16	2	25
17-20	2	25
21+	1	12.5

Source: Interviews by the author.

The respondents also have significant experience with research. Table 5.2 shows that 62.5% of the respondents have been in charge of more than five projects over the last 5 years, while on average 6.5 projects have been initiated by each researcher. No single definition of project was used. Instead, respondents were asked to determine what they thought constituted a project.

Table 5.2. Projects undertaken by interviewees in the past five years.

Number of projects	Frequency	Percent
0	0	0
1-5	3	37.5
6-10	4	50
11+	1	12.5

Source: Interviews by the author.

Canola breeding is conducted using traditional breeding methods or biotechnology methods (or both). The majority of the canola breeders that were interviewed (6 out of 8) are involved in biotech research; two were involved only in traditional plant breeding (see Table 5.3).

Table 5.3. Projects undertaken by interviewees in the past five years.

Research Type	Frequency	Percent
Traditional	2	25
Biotech	2	25
Both	4	50

Source: Interviews by the author.

With regards to the kind of research canola breeders are engaged in, three types can be recognized: basic; applied; and development. As table 5.4 shows, most of the research projects are directed towards applied research and development (i.e. the development of varieties, germplasm, field research, commercial development etc).

Table 5.4. Interviewee's funding according to type of research

	Frequencies		
% funding	Basic	Applied	Development
0-10	4	0	4
11-20	1	2	0
21-30	0	1	0
31-40	1	1	0
41-50	2	1	0
51-60	1	1	2
61-70	0	0	0
71-80	0	0	2
81-90	0	0	0
91-100	0	1	0

Source: Interviews by the author

5.3. Increased Protection

One of the defining features of research in the last ten years is the increasing rate of IP protection activity. Respondents indicated that 85% of the new varieties on average are protected by PBRs in their institution. Eighty percent of respondents indicated that use of PBRs has increased over the last five years. Interviewees were also asked if they had increased their patenting of research tools over the last 5-10 years. Five out of seven (70%) indicated that they had. Those who answered affirmatively were further asked to indicate the reason for increasing their patenting. The increase in patenting was 57% "in response to the patenting of others to ensure freedom to operate" and 43% "to ensure that R&D expenditures are recouped." Figure 5.1 provides a breakdown of the reasons given for increased protection activity.

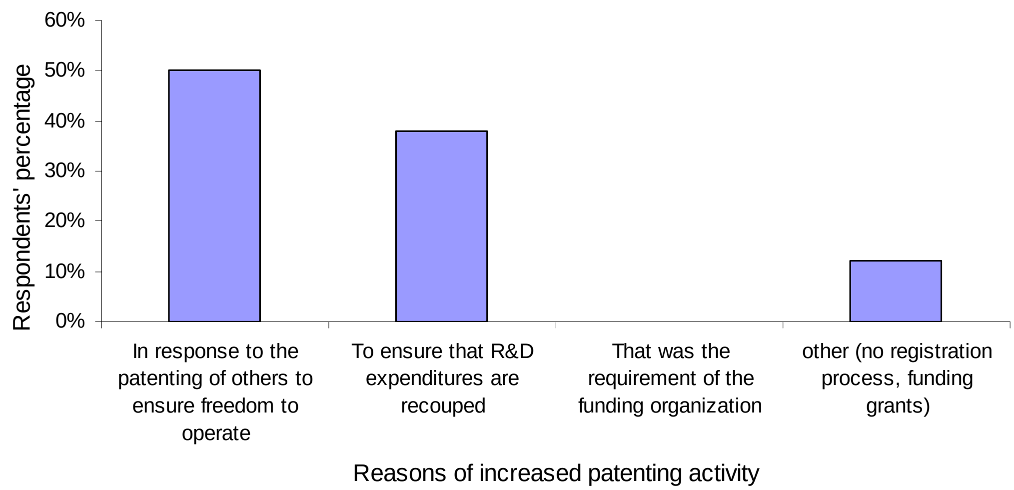

Figure 5.1. Why patenting activity has increased.

Source: Interviews by the author.

5.4. Lack of access to public material

Prior the proliferation of IPRs, scientists used publishing to ensure freedom to operate. Other breeders could also use the results in their research projects, providing they cited the author. According to the respondents, IPR legislation has rendered publishing a second best solution, as can been seen by the following quotes:

Interviewee 3: "They want to patent first and then publish…we have been able to present posters and papers but we had to do the patent[ing] first."

Interviewee 9: “We have thought about it [publishing], but I can’t say we have done it. We have discussed that…but as long as we have something patentable we will try to patent to make sure that we will have freedom to operate and that we have something to trade.”

Interviewee 2: “That [publication] is what I would do in cases where there wouldn’t be the possibility to protect IP but if we feel it should be in the public domain we would publish.”

One of the reasons why patenting is preferred to publishing is that publishing does not always prevent firms from patenting published material. Interviewee 4 explains:

“I think the perception is that it [publishing] does give you protection for being able to practice the research, but it doesn’t. I think that is a misconception…the patent system is based on commercial utility. Scientific publications in many instances don’t allow or support commercial utility being described in a scientific paper. In fact, some companies may look through published data and file a patent on the information if it could have commercial value to or impact on the company. Even though they may not have done all the experiments. As long as a company can reduce it to commercial practice and it is novel etc., it can do that.”

The inconsistencies from the Patent Office regarding the application of rules is another factor that renders publications an insecure mean of achieving freedom to operate, granting patents an advantage over publications. As interviewee 21 describes:

“…the examiners in the patent offices are not consistent in how they apply the rules, resulting in [it] being difficult to make filing decisions. Therefore, while you may feel that you don’t have to file a patent because there is sufficient information in a publication to prevent someone else obtaining a patent on it, the contradictories and inconsistencies in the patent office make it risky to not file on your own research, particularly if you want to have the freedom to practice your own technology."

Researcher: "Does this mean that other companies patent published results?"

Interviewee 4: "Yes, and it has been done. There are lots of examples."

An example where publishing didn't work was provided by another interviewee:

Interviewee 10: "We have one example where we essentially tried to publish on yellow seed but there were two companies who patented on yellow seed even though we had massive amounts of public disclosure."

From the preceding analysis, it is emerging that patenting is more preferable than publishing. This would mean that as institutions turn to patenting to ensure freedom to operate and to reap the fruits of excludability, enriching the public domain with new knowledge becomes less important. As a result, the public pool of knowledge, from which every R&D organization draws knowledge, may be shrinking. Indication of such a scenario is found in the interviewees' quotes:

"But almost everybody in our industry can see the fact that the freely publicly available material for release without any burdens has dried out. So we are really locked in a point where 1995, 1998, 2000 was the last time where you could freely access material germplasm and that changes. So anyone that has not access to that material is, in long term, going to find it pretty difficult." (Interviewee 1)

"…We will come to a point where knowledge, germplasm that is available from here will be exhausted to the extent that companies have more." (Interviewee 23)

"One of the difficulties with having the private sector doing research to improve their product is that they seldom publish what they discovered. This is an impediment in many areas. I think of work done on the environmental aspect of transgenics where I know that companies have done a lot of good work but you will never see it published. But knowledge really should be shared so that everybody is better informed and be able to built on that knowledge and know the pitfalls and things to avoid." (Interviewee 7)

To provide further information on the extent to which research results are publicly available, interviewees were asked "What proportion of research tools you have developed goes to the public domain?" On average, responses indicated that only 22.5% of research tools are available to the public. The percentage is quite low if we take into account that the majority of interviewees (five out of eight) work for public institutions.

5.5. Access to proprietary tools

5.5.1. Access to key technologies

To determine to what extent scientists have access to essential research tools that are owned by others, interviewees were asked to indicate whether there had been any case where they could not get a research tool or germplasm and decided to cease the project. Sixty two percent answered affirmatively. Those who experienced blockage were further asked to reveal the reason(s) for not being able to get the necessary research tool. Almost half of them stated that the owner of the tool was unwilling to share it and one quarter said the negotiating parties had conflicting agendas and could not reach an agreement with all the rights holders. Other reasons include negotiations break down, high royalties and incomplete transactions (i.e. the agreement was never fulfilled). Figure 5.2 provides a breakdown of the reasons to for blocked access to research tools.

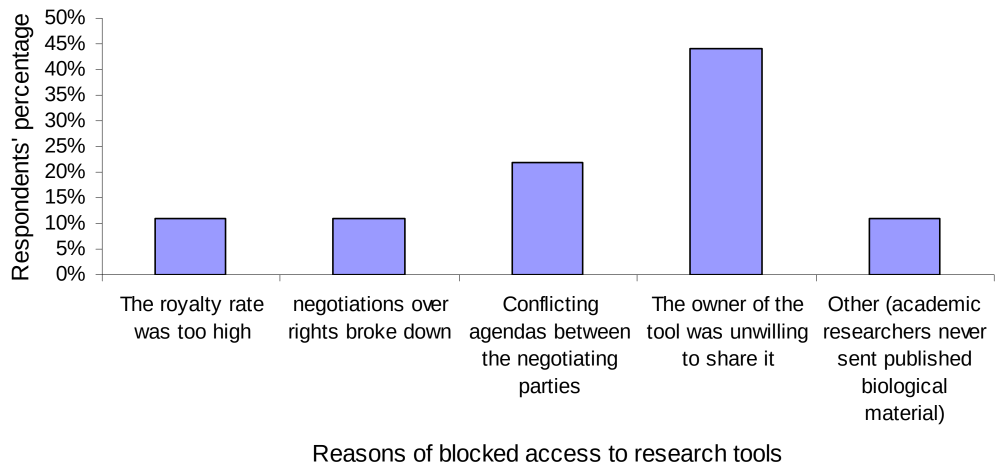

Figure 5.2. Why access to research tools is blocked.

Source: Interviews by the author.

5.5.2. Transaction Costs

In the previous chapter we saw that transactions are not costless and that various types of transaction costs exist. Transactions of IPRs are no exceptions. The contracting parties, in our case R&D organizations, have to put formal arrangements in place that regulate the conditions under which licensing will take place. Such arrangements often involve negotiations between the licensee and the licensor and the compilation of legal documents that will reflect, in a formal way, the obligations and rights of each party. These tasks are usually undertaken by lawyers, IP officers and negotiators. When the volume of IP increases, the costs related to the management of IP are expected to rise.

In examining whether transaction costs have increased over the last 5 years, interviewees were asked to indicate if the number of persons involved in the IP management in their organization had increased. If there had been an increase, breeders were asked to reveal the number of persons involved in managing IP five years ago and today. Five out of eight breeders indicated that an increase in the number of people dealing with IPs had occurred while three said that the number has remained steady. Two people on average were involved in IP management 5 years ago according to interviewees. Nowadays the average has tripled (6 people). However, the majority of breeders, in response to the question if they require more IP related services (e.g., lawyers, IP officers, negotiators) compared to five years ago, responded that they do not. More specifically, only three out of eight indicated that they need more IP related services.

The increase in the number of persons involved in IP management at the organizational level in combination with a need for more IP services compared to the past suggests that, during the last 5 years, there has been an increase in the volume of IP which called for more IP related personnel. R&D organizations have extended and better organized their IP departments to respond to the increasing IP volume. As interviewee 14 stated "…we have very strong in-house legal team and we have a well defined process, so, for example, if there is something valuable I feel I want to document, [I] get [an] e-mail off and someone evaluates it quickly." Another interviewee (5) shares a similar view: "Our IP department has grown substantially and is now somewhat more streamlined".

With regard to the time devoted to IP management by the breeders, one and a half more days per month on average are needed to handle IP compared to five years ago. In one case, however, the time spent on IP is three days less per month. The reason is that in the past, due to insufficient experts on IPRs, some breeders were assigned IP duties in addition to their research duties. The result was a loss of research activity. As interviewee 8 pointed out "…it can be incredibly distractive from research if you have to write patents". However, this situation has started to change. As IP offices were becoming more organized, IP responsibilities were passed on to people trained to deal with IP issues. This freed some breeders from the burden of paperwork and bureaucracy. An example is given by interviewee 17: "I have some background in negotiating agreements and I even have some background in writing them, and I was really quite prominent in doing that for the first four years…but after that we had a large number of reorganizations and the business office has separated much further from the researchers, so for me the amount of time managing those kind of things is less, I think that is very typical".

One component of transaction costs is search costs. In canola research, search costs include the time spent to trace patents on particular research tools or genes.

Breeders want to make sure that their invention doesn't infringe on someone else's patent in fear of the "hold-up" problem (Shapiro, 2000). The hold-up problem refers to situations where "each party to a contract worries about being forced to accept disadvantageous terms later, after it has sunk an investment, or worries that it's investment may be devalued by actions of others…" (Milgrom and Roberts, 1992, pp136) To avoid the hold-up problem breeders and/or IP officers have to watch for possible patents. This may imply the acquisition of certain software or data bases that help track the patents. It also involves work, possibly from hired lawyers or consultants, in identifying the scope of the patent and determining its level of threat to the current invention. To examine to what extent breeders check IP access (either by themselves or via their organization's IP office), they were asked to state the percentage of cases where they look into research tools access. Seventy percent answered that they always look into IP access when they use a research tool. Fifteen percent (1 breeder) checks access in 50% of the cases and the other fifteen in 80% of the cases. These answers clearly indicate that freedom to operate is a concern for the scientists.

Another type of costs necessary for a transaction to take place is negotiation costs. The licensor and the licensee will have to agree first on the conditions of licensing before the transaction takes place. The breeders were asked to state the frequency of negotiations' occurrence in their research projects. More specifically, "For the two most important projects/programs you are working on, how many pieces of IP did you have to negotiate?" The majority of the breeders (five out of eight) answered "none", while three of them reported at least one case where they had to negotiate. Negotiation costs are not confined to the money value required for their accomplishment; they also involve time loss and failures in bargaining due to non-economic reasons such as cognitive biases (Heller and Eisenberg, 1998). The following quotes illustrate the costs associated with negotiations:

"You end up dealing with an additional layer of people who are doing the negotiating and they may not understand or not fully appreciate the implications of not reaching an agreement. The time factor here is substantial; it takes forever to get the two parties to come to some sort of an agreement. Both sides have lawyers and they rarely agree on wording. Usually what they are trying to protect is not worth the cost of the negotiations." (Interviewee 7)

"…I think it is much better keeping the business office out of the picture until you actually decided, because they tend to make things much more complicated than it really is." (Interviewee 8)

"In some cases we don't use it (proprietary material), just because the negotiation process can be painful, it takes a lot of time and sometimes the financial terms on these traits or resources are, in my opinion, unreasonable." (Interviewee 1)

"…however negotiating parties can have conflicting agendas…and the owner of the tool may be unwilling to share the tool. They want to hold on to everything they got." (Interviewee 18)

Negotiation costs are particularly burdensome for small firms that lack a strong or a cost-efficient legal team; as interviewee 7 indicates, "The cost of negotiating maybe out of reach for a small operator."

In some instances the negotiation process can be so lengthy and severe that some individuals start using proprietary material without license under the expectation that the license will be obtained sometime in the future. In this way, it is hoped to have some time that would otherwise be lost because of negotiations. As interviewee 16 describes: "…sometimes when the license is being negotiated we start the work and we start negotiating the license. Because I have one example when the negotiation went for more than 10 years so we did a lot of work before we actually finished negotiations."

The quotes presented above indicate that transaction costs and IPRs are positively related. However, IPRs could potentially reduce transaction costs. The interviewees were asked to indicate instances where IP rights have reduced transaction costs. Five out of nine scientists responded that there were no such cases, while four referenced some. When interviewee 14 was asked to indicate cases where IPRs reduce transaction costs he responded: “Absolutely, if you can negotiate very early with competitors [and] if you have the ability to cross license, have technology that matches up well then [you can] cross license and make the deal very quickly…”, Interviewee 21 indicated “I would say they have reduced transaction costs in some cases because if you do your own intellectual property development you don’t have to license it back if someone makes improvements and patents them”. Interviewee 15 expresses a similar idea, “If it is clearly defined, you know where you are going so in this case it cuts negotiating time down and a lot of paperwork that has to be done with it, so that would definitely mean reduction in time and money.”

From the preceding analysis it seems that IPRs involve transaction costs, particularly negotiation costs. Some of these costs like filing costs and IP personnel wages are difficult to avoid. However, other kinds of costs like the time a negotiation takes can be cut down. In any case, transaction costs should not be overlooked as they do affect research material exchange and access.

5.5.3. Research exemption

Access to proprietary tools by the scientific community has been a concern for policy makers. Both the Canadian Patent Act and Plant Breeder’s Rights include a research exemption. The research exemption aims at minimizing the adverse effects of IPRs while preserving the incentive to invest in R&D. Under certain conditions it grants the right to make use of a proprietary invention irrespective of the owner’s consent. The conditions have to do mainly with the purpose of use of the invention in question. In particular, in the Canadian Patent Act, the use for which the authorization is sought must be “*a public non-commercial use*” (section 19.1, subsection 2) for governmental use and “*the purpose of experiments that relate to the subject matter of the patent*” (section 55.2, subsection 6) for private use. Thus, a patent may be accessed by the public and the private sector for research purposes only. The research exemption in PBR is implicit in the definition of rights under the law (PBR section 5(1)).

Both acts seem to have taken precautions regarding access to proprietary inventions by the breeding community for the advancement of science. However, the above enactments are often believed to be inadequate and vague. Conditions such us those of section 1, subsection 1 of the Patent Law Act allow for a wide interpretation. The application of research exemption may differ from case to case, creating uncertainties for R&D firms and breeders regarding its effectiveness and application. To examine if breeders trust, use or know of the research exemption they were asked whether they think they have a research exemption for patented material. Six out of eight answered they do not have a research exemption; one was not sure and one answered that he/she has. Here are some of the interviewee's responses:

"No. I have to worry about them [patents and PBRs] all the time." (Interviewee 18)

"My understanding is that the research exemption in Canada and in the US doesn't actually give an exemption to conduct research on a patented invention. It only gives an exemption for research that would improve the usefulness of the patented invention. So I don't believe there actually is a research exclusion for the purpose that researchers would like one, which is to allow research using the patent. I don't believe that exists." (Interviewee 17)

"I am not sure, at this time we are not using any kind of research exemption. We don't usually operate under research exemption, we usually have research agreement. So we are not using [a] technology and we assume we have the right to use it, if we want a technology from a company we sign agreements, saying that we have the right to do research as opposed to the right to commercialize." (Interviewee 9)

"I am going to say no because I know what company's principles are. So 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." (Interviewee 1)

These quotes indicate that research exemption is not being used by the majority of the canola breeders because it provides coverage only to research conducted for non-commercial purposes. Since the main focus of private and public canola research is the production of new products and traits with commercial value, the applicability of research exemption to contemporary canola research is low.

5.6. Access to current material

The exchange of ideas and views among researchers is an important part of science. As new information is being circulated and new experience is gained, scientists acquire new knowledge. The sharing of views within a research community contributes to the learning activity of those who produce scientific output, thereby advancing science. Events like conferences and workshops have been devised in academic, research, administration and other communities where individuals have the chance to meet and discuss ongoing research and contemporary issues. In many instances, these conferences offer the chance to meet new people in the same industry or area of interest, forge relationships and even create partnerships. Communication, therefore, in this sense reaps multiple rewards to scientists and those involved in R&D.

Canola breeding has had a tradition of an open research community. Due to the public character of canola research in its early years of development, the information developed for the crop was diffused throughout the industry. Researchers from different agencies and organizations cooperated with each other and worked collectively (Gray et al., 2001). The result of this endeavour was the development of canola. Today, with IPRs in place, the research environment has changed. Breeders and organizations appear more reluctant to share information among themselves. The fear that a competing laboratory will invent and patent first, wasting the investments made by a laboratory for a particular project, makes actors reluctant to share not only technical information, but also information regarding current research and areas of interest. The most common way to protect these areas when research is not yet complete and patents have not yet been issued is to keep the research secret.

To examine the extent to which breeders are willing to discuss their research with other breeders, interviewees were asked about their views regarding secrecy. Two thirds of the breeders strongly agree or agree with the proposition that secrecy has increased over the last 5-10 years. Figure 5.3 shows the full distribution of the responses.

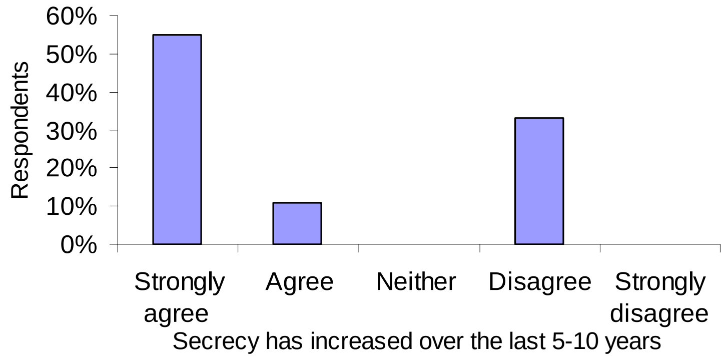

Figure 5.3. Secrecy over the last 5-10 years.

Source: Interviews by the author.

The interviewees' views about secrecy underscore the argument that a transition is underway from a liberal regime regarding the flow of knowledge to a more restrictive one. The breeders that were interviewed expressed a number of views about this matter.

"So, secrecy yes, it has gone up. Breeders used to share. It was who had the best selection program. You truly trade some lines, you know, I am looking for certain fatty acid profile line and you might say yes, I have got one of those and then they may ask you for some. Breeders would trade stuff. The real gain was to see who could come up with something before the other. But they would try to assist each other because it was sort of like left and right hand situation. If you never shared any of your stuff, you never got any new stuff. So you had to depend on yourself solely. The more you shared, the more you got back, in general. So public plant breeders always worked in that premise. And over the years it worked. But that has gone away to some degree. Now you have public institutions tied in with private and you have to be more careful in what you are doing." (Interviewee 10)

“A number of years ago we had canola industry days and canola meetings. The breeders and the industry would stand up and describe what they were working on. It seemed to be very open and people would ask questions. As years have went past there is less and less of that, there is less companies standing up and say this is what we are working on and as government, we used to work with anybody. Now we do not say anything. We are told by the business office “you can’t do that”, “you can’t say this”. We have prior knowledge here, we can’t go and discuss it elsewhere and they concern about patents and freedom to operate and things like that, so I think it is really coming down from the business office in terms of what we can say and what we can’t.” (Interviewee 22)

“We used to sit down at coffee and discuss our research and all sorts of interesting comments and suggestions would come forward to help. You don’t dare to do that anymore and from that perspective you lose something, you lose the outside view, a different perspective. You lose the opportunity to broaden your project or improve your project with what somebody else knew from pathology, entomology or genetics. It tends to restrict the dissemination of knowledge…over there we could get a coffee and sit down and brainstorm, two-three times a week. And then another scientist would come over and say how we could fit in with what he was doing and so on. But we had no formal agreement. Nobody signed anything and it all came in together and resulted in something that was truly significant.” (Interviewee 7)

“My reading of it is that the government institutions are really interested in proprietary rights now. They were not in the past. They are interested in owning and licensing any of their inventions. For that reason they don’t want to talk about what they are doing, only after it has been done. Whereas in the past all those discussions were going on all the time, about what I was doing, what they were doing because it was all of them completely into the public domain. But that has gone away in the emphasis on proprietary rights by the government, wanting to own patents and license those patents or sell them.” (Interviewee 11)

"…I have always considered that willingness to discuss your current research with others was a key component of having a successful operation. This approach has certainly been curtailed to almost an extreme at the present time." (Interviewee 18)

"Everybody knows what everyone else is doing but nobody talks about it. It has increased to ridiculous levels." (Interviewee 20)

"There was one case last week. A visitor wanted to come and talk to me but the business office was concerned about this person and the possibility to take information and see what was going on in the rest of the lab. That's not the way I like it. A number of years ago this wasn't a problem. We had people coming and talk with them. I think everybody seems to be closing up and there is not much freedom of information." (Interviewee 3)

"Secrecy has increased over the years. The sharing of ideas for the development of cultivars and germplasm among plant breeders still exists today, but some approaches are not disclosed because of their potential economic impact on the industry. This is all the result of IP protection legislation that was introduced over the last few years. It's all money driven. Before that the goal was to develop new cultivars and publish scientific research in peer reviewed scientific journals. There always was some secrecy about the research I did, because I wanted to be the first to come out with new exciting developments." (Interviewee 2)

There are breeders who disagree that secrecy has increased over the last 5 to 10 years. For example, interviewee 12 indicated that "I don't think secrecy has increased over the last five years, maybe in the last ten years. I would generally disagree with that." Also, interviewee 6 disagreed and responded that in the last three years it has actually decreased.

Overall, the responses indicate that secrecy has increased compared to twenty or thirty years ago. Organizations have recognized the trend and have worked to address it. For example, interviewee 22 said that "With regard to other government institutions we are more likely to work together with other…institutions, they are trying to promote us to work together because in this way we can provide information easier. It is the same for Universities but with private industry it seems to be very difficult to give them more information." So, for governmental institutions, which up to a point share a common goal of producing and providing public goods, it seems that secrecy can be fought through cooperation. For private firms however, apart from formal collaborations, secrecy is likely to remain.

The difference between secrecy in government and private organizations is reflected in interviewees' views regarding the likelihood of competing organizations sharing research tools or germplasm. Figure 5.4 reveals that the likelihood of sharing is low in the canola industry. Universities and private industry are "very likely" to share research material with other laboratories. The views on governmental institutions are diverse and no trend can be drawn as to the likelihood of sharing.

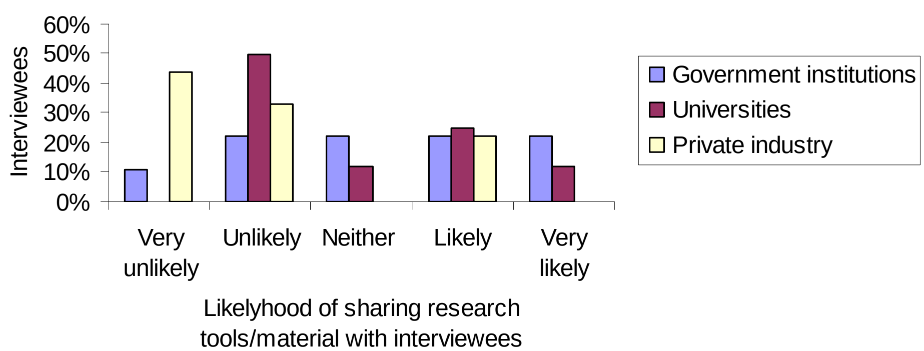

Figure 5.4. Likelihood distribution of research tool sharing among canola breeders.

Source: Interviews by the author.

Up to now, sharing was examined by measuring third parties willingness to provide research tools. Another way to check the sharing that is going on in canola breeding is to ask breeders directly if they have ever denied a request for a research tool and the reason for doing so. Table 5.4 shows that half of the interviewees have refused at least one time, if so, a research tool. Furthermore, interviewees were asked to indicate one or more reasons for doing so. Interestingly, as figure 5.5 shows, only 30% of the reasons relate to scientific competition. The remainder concerns reasons exogenous to the research community such as contract forms with the funding agency, commercial concerns and institutional requirement. It seems that the introduction of IPRs has affected directly and indirectly the behavior of breeders regarding the sharing of research tools.

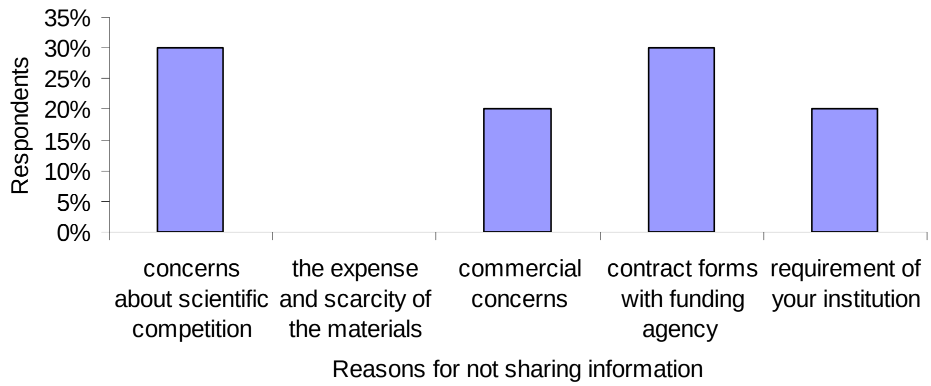

Figure 5.5. Why information is not shared among canola breeders.

Source: Interviews by the author.

5.7. Collaboration in Canola R&D

Historically collaborations have played a prominent role in canola breeding efforts. The creation of canola itself was a result of various actors' participation (e.g. AAFC, RAC) at the technical and the funding level (Gray et al., 2001). In recent years collaborations are useful for one more reason: they are a way of potentially bringing together pieces of intellectual property owned by different organizations, enabling the realization of new technologies. In this way, they contribute to knowledge generation overcoming the IP barriers. Below are some benefits of collaboration as recognized by the breeders:

"It has made us vastly more productive." (Interviewee 17)

"Generally it has a positive impact. Working with industry in collaborative projects is always rewarding because industry works in a different way and sets different targets. So you get a different perspective on how they actually apply the results that we generate from the projects. Working with plant breeding industry, they have very large number of plants, a huge number of plants and samples going through labs. We get very good feedback on how utilizing the tools" (Interviewee 12)

"…they also allowed us to do research in areas where we now would not have been able to do. It allowed us to prepare the next generation of germplasm that we could offer once we had exhausted present type of material." (Interviewee 23)

"Collaborations have given us access to other germplasm and to other research facilities." (Interviewee 9)

"…allow research in areas otherwise blocked." (Interviewee 2)

However, collaborations are far from being a solution to the tragedy of the anticommons. First, there must be a profit incentive for two or more organizations to collaborate. This means that the venture must be profitable and that each contributor will gain from participation. The profitability of the venture depends on two factors: the total revenues acquired by the commercialization of the new technology and the costs implemented for its realization. Even though the former can be assumed as being independent from intellectual property rights, the latter is not. The various owners of IP, in a hypothetical example of collaboration, will have to come to an agreement to a number of issues such as technical issues, the economic exploitation of the new technology, possible restrictions, each participant's share of the costs and the profits and so on. Consensus on these various subjects is not achieved without cost; extended negotiations, paperwork and enforcement of the agreed terms requires legal and other related services. The higher are these, the less profitable is the venture. If the total costs are high enough or the revenues are low enough or both, the collaboration will not take place. Therefore, it seems that collaborations may be a solution to the patent thicket problem when the new technology is profitable. Problems may nevertheless arise if the technology has high social benefits but low private benefits. Interviewee 18 describes such a case:

“…one of the things that I could never understand is why couldn’t we put together a consortium, to have varieties resistant to the diamond back moth; the genes are known and available and we have the pest that is here frequently…the chances of that population developing resistance to the genes at least from a perspective of Western Canada, is really not a good reason for not having our varieties being resistant. I think the problem was first that the companies did not want to release their genes to a consortia. Second was the difficulty of recovering research costs because you would be selling protection insurance, since the insect is not going to be there every year so how can we charge. If we charge a fair amount of money for the presence of that resistance gene and the farmer would say well, it is going to cost me more than a variety that hasn’t got it so I’ll bet that this year I won’t have to spray for diamond backs. But we should have it done, we still should do it, on a cooperative basis. It has been suggested many times but we haven’t been able to put it together. There are too many pieces in too many different places. It is an example of how the germplasm and knowledge don’t always overcome the profit motive, the knowledge is there but the will and the profit isn’t.”

Second, for collaborations to solve the anticommons problem, the resulting technology should be made available to the research society. The reason is that if the new technology is protected by IPRs and cannot be used for the research of other technologies by third parties, it creates anew a tragedy of anticommons. With collaborations, existing technological pieces may be brought together, but if the output is proprietary, all that collaborations do is transfer the IP problem to the future. Therefore, collaborations do not solve the tragedy of anticommons but rather postpone. In the pyramid framework that would mean that if IPP1 and IPP2 technologies could be combined due to collaboration among the two owning firms and the resulting technology (IPP3) becomes proprietary, the realization of downstream technology, e.g. Tech 1, can only be developed if access can be obtained for IPP4. If IPP3 and IPP4 are held by different owners that have the incentive to block each other from accessing them, then Tech 1 will not be developed.

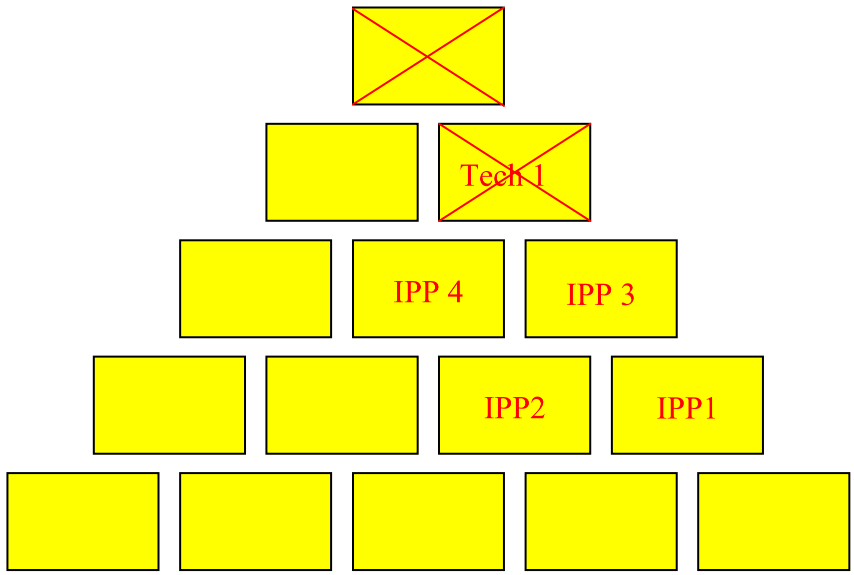

Figure 5.6. The tragedy of the anticommons created anew.

The nature of collaboration's research output is highly dependent on the ownership structure of the collaboration. If the collaboration takes place between two private companies, the new technology is expected to be proprietary: without ownership it is doubtful that the two firms could recoup their investments. Therefore, in this case, the majority of the research output can be expected to be protected. If the collaboration takes place between two public organizations, the produced technology could be made publicly available: the purpose of public institutions, at least theoretically, is to deliver public goods to society. However, the prospect of two public institutions collaborating is neither attractive nor likely. Interviewee 23 explains:

"It [the collaboration] is mainly with private sector, public sector is more on a level where you go to meetings, meet the other researchers, exchange ideas if you like to do so, but no formal agreements in the sense that we have with the private industry. We have these formal agreements because public sector organizations don't have money to give, we are going out to get money rather than exchanging money with other public institution, that wouldn't make much sense."

In recent years, public research organizations are vividly engaged in patenting activity. The reduced budgets for public research that Canada has experienced in the last years is another reason public organizations are more likely to collaborate with private industry rather than with other public institutions. As interviewee 2 indicates:

"The impact that it [collaboration] had was on our ability to continue the work that we do with dwindling federal research funding, especially after the 1995 budget and a series of cutbacks. We had germplasm of interest to the industry. The outside funding allowed us to do research that is of value to Canadian agriculture and to canola in this case."

In examining the dependence of public institutions on private funding, canola breeders were asked to state the total outside funding received over the last 5 years as a percentage of their total resources. From the four responses that were obtained, the average percentage is 70%, illustrating that a large proportion of public research is being funded in conjunction with private industry. Therefore, it seems that public institutions are more likely to form collaborations with private firms rather than public organizations.

Unlike the collaborations among public institutions, where the resulting research is expected to be publicly available, collaborations between public and private partners are very likely to engage in patenting activity. As interviewee 13 explains,

"For projects where we are getting funding from the government then it makes sense that we try to get the data available to everyone in the community as quickly as possible. But when you have these projects with companies we have to develop specific agreements related to how are we going to manage the data, how long it has to be confidential and then we have to respect those agreements because obviously they have responsibilities to produce cultivars that have a commercial advantage. We are always going to have that aspect when we are working with companies."

“Usually, in multiparty agreements, Canada has the ownership and Canada itself has the right to exploit, but all of the collaborators have equal right to exploit, it is a non-exclusive right. Quite a lot of time, Canada also has the right to license to third parties but at a cost considerably above the cost to the original companies collaborating with us in the research.” (Interviewee 17)

It seems that private sector pushes the public sector towards patenting activity; the result is that the public sector may be doing more patents than it otherwise would. To check if this holds, interviewees were asked to state the impact of their collaboration on their intellectual property activity. Here are some of their responses:

“PBRs was something that industry funding required us to do and more and more the interest of patenting technology that comes out of the collaboration with the industry partner and those applications for patents are just being submitted or being prepared. They have not yet issued but that is getting more and more the case.” (Interviewee 23)

Researcher: “So, do you argue that your collaborations increased your IP activity?”
Interviewee 12: “Well it does, yes. Private industry is very keen on agreements…”

It seems the research output produced by private and public partnership becomes the subject of protection mostly because in this way the private sector enables the commercialization of the technology and the recoupment of the costs. For the public sector, the assignment of IPRs to the new technology has a positive and a negative effect. The positive effect is that public organizations secure vital funding for the continuation of their research while the negative concerns the production of proprietary instead of public knowledge. The latter effect has been an issue lately and public organizations are starting to raise the question of what is going to be proprietary and what is going to be public from their collaboration with private firms. Interviewee 8 explains:

“Historically we develop them with a high percentage of industrial money, at the beginning we were making agreements where everything that was developed with the public money and the industry money was confidential because the industry wanted to do it that way. In the last four years we have been negotiating very hard for the proportion of things that are developed using public money to go to the public domain and the proportion of things developed using the industry money don’t go to the public domain. Then, genomic tools that have been developed using public money has all gone into the public domain or will go into the public domain. So probably about 30% of what is developed currently has gone to the public domain and then 65% will go to the public domain in the future.”

Interviewee 13 makes a similar point:
“We try to ensure that agreements allow us to publish aspects of the project and if this can be arranged then we have productive projects. So, for example, with developing genetic markers, you have sets of sequences developed that are maintained as proprietary information, however, the markers that come out of that produce genetic linkage data that we want to be able to publish. For the Brassica Single Nucleotide Polymorphism (SNP) marker project which is now ongoing we have directly combined an aspect of public availability to a 1/3 of the sequence data we are generating. The other 2/3 will remain proprietary. This was done because we had requests from the Brassica genetics research community indicating that it would be really beneficial to the community to have the right to use a portion of the SNP markers being generated. Researchers will be free to use them as they wish. So that is a normal thing that we do with the new projects, to ensure that a portion of the sequence data will be publicly available.”

Therefore, it is observed that collaborations between public and private firms result in a shift from fully to partially proprietary knowledge. The research community benefits as public organizations ensure that a part of the research output is published. The existence of published portion reduces the likelihood of a tragedy of the anticommons, although it does not rule it out.

5.8. Infringement

In other industries, like music and software, piracy is widespread (check Romer). However, piracy is most likely to happen when the infringers are large in numbers (e.g. consumers) and litigation becomes prohibitively costly, rather than when the infringers are few, easy to trace and profitable to chase legally (e.g. private firms). The canola industry falls into this second category. Even though some R&D organizations, particularly public, may not have the funds to challenge infringers, canola breeders, private and public, show particular caution in not using proprietary material without a license. To the question "How often do you use patented material or processes without a license?" all of them (9 out of 9) answered "Never". Also, when they were asked how often they look into the IP access of the research tools that they use, five breeders answered always, one answered in 80% of the cases and one in 50% of the cases. These results indicate that canola R&D firms do not consider infringement as a strategy to overcome IP barriers. As interviewee 17 explains, "I think for an organization that has limited liability, ignoring things is a possibility. For X which does not have limited liability I think ignoring patents it is not an option. I think some of the patents could be challenged in court, but it is a very expensive business and you have to be able to make a lot of money by bringing down someone else's patent in order to make a court based solution viable."

5.9. Inventing around

Inventing around in plant breeding is another mean of overcoming a patent. Patents usually protect ways or methods in achieving a particular result. In order to reach the desirable outcome, R&D organizations have either to obtain a license from the patent holder to use the protected process or to find a new way that yields the same result. When the former is unattainable (e.g. when the required royalties are too high), R&D firms devote time and money to invent around the patent. A successful inventing around can be then licensed to third parties and can act as a competitor to the original patent. A common feature of inventing around, however, is the use of different methods than disclosed in the patent. Firms that invent around often change marginally the original method so that the new one does not infringe the patent, while being able to generate the desirable outcome. The problem arises when the marginal changes are unclear as to whether they infringe or not the original patent. In this case, the dispute is resolved in courts, often at substantial cost.

Therefore, the tactic of inventing around has both advantages and disadvantages. Avoiding a patent and the high possibility of litigation are the obvious ones. The following quotes outline views on inventing around and throw light on some of its positive and negative aspects:

"I have myself invented around the IP or trademark, but that is costly…if it [inventing around] is successful it may lead to significant economic activity." (Interviewee 11)

"Invent around is always a possibility and is often used. Again, why should I invent around if a technology already exists? When you invent around you have to be different from the original invention and in many cases this is difficult to achieve. This is particularly true for patented products where inventing around is virtually impossible. Furthermore, there is a possibility the owner of the original invention to claim that is not new. I don't know of a successful inventing around. So I don't know what the point of inventing around is, but there are other institutions which do that or try to do that." (Interviewee 2)

"I know several projects to invent around patents; I know of about $700,000 of research funding going historically into that research area, but I think scientists are becoming much more reticent about doing this type of research, especially in a climate where publications are so big a component of a scientist's output. Inventing around doesn't lead to publications. Doing something in a slightly different way than someone else did several years before, isn't the sort of thing that researchers are trained to do. We want to be first, it is part of the motivation of the job." (Interviewee 8)

From the above, it becomes apparent that while inventing around may lead to new discoveries that can be better from the original, in many cases the invented method does not deviate much from the original. This has two consequences. First there are small incentives for the researcher to repeat other's work in a slightly different way and second there is a high probability that both the patent holder and the inventor to be engaged in a legal dispute. Therefore, inventing around, even though it can be used to overcome IP barriers, does not seem to be appealing, at least at the researchers' level.

5.10. Difficulties with R&D

To check the severity of the consequences of blocked access to research materials, interviewees were asked to indicate whether there had been any cases where they could not get the research tools/germplasm and decided to cease the project. Five out of eight answered affirmatively. The following quotes describe several instances where blockage caused problems:

"…we thought we had access to the market where were selling a product and a submarine patent popped up and the submarine patent blocked us from having market access and so it has been extremely difficult to negotiate with a patent owner because our base germplasm was so much better that they refused to give us rights to the patent even though we were first to market it…" (Interviewee 1)

"There are two specific ones, one where they just wouldn't agree with the terms and conditions by the crown and the other one…they were unwilling to share because as a public company we didn't have a commercial arm." (Interviewee 5)

"I know of a number of projects that didn't receive federal or provincial funding because of concerns over freedom to operate. I do know of projects that were stopped because patents that were submarine for years in the Canadian patent system actually came out and it became obvious that the organizations doing the research would never be able to commercialize anything. " (Interviewee 17)

"The intellectual property was a transgenic trait and in that case the real reason was that the regulatory costs would be too high and then the company who had the intellectual property would have to take on the regulatory cost but they were not willing to do that." (Interviewee 16)

"The cost was too high. It was prohibitive to obtain IPRs. Sometimes [the cost] is as high as the research cost." (Interviewee 19)

Canola breeders were also asked if the length of time that research takes has increased due to stronger IP protection. Two out of seven believe that it has significantly increased, three that it has somewhat increased and two that it has not increased.

Breeder: "In terms of negotiating licenses, absolutely. Lot's of delays. But in terms once freedom to operate is there, then [it is] ok."
Interviewer: "Any sense of the maximum delay that you have experienced?"
Breeder: "There was one actually that it took 3 or 4 years. Just because of the inability to negotiate with the competitor." (Interviewee 14)

"In one of our programs we delayed for about five months because we were not able to get the material sent to us, so there has been a delay there." (Interviewee 22)

"Yes, I think the answer would be "yes, it significantly increased"…I think the scientists are compensating by finding ways to be expected to write patents for technologies that will never actually go anywhere…It can be incredibly distractive from research if you have to write patents." (Interviewee 8)

"It is increased somewhat. I think sometimes are delays when negotiating licenses or MTAs." (Interviewee 9)

"It takes longer to commercialize it but I don't think it takes longer to complete the research." (Interviewee 2)

Therefore, the proliferation of IPRs seems to have caused impediments to canola research, both in terms of delays and cancellation of research projects. As interviewee 7 explains,

“I believe that the present Plant Breeder’s Rights 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. I think that is wrong. Germplasm exchange has become a particular sensitive issue and unfortunately it has become, at least with canola, a real constraint to making significant industry wide improvements. I would say that X, in its zeal to try and capture some of the benefits of patenting and plant breeder’s rights, have made the exchange of basic material much more difficult than it ought to be. I don’t think there are many that would disagree with that assessment. It is making it difficult to build on the advances of others because plant breeding relies heavily on the ability to use as platforms, the best varieties and innovations to make the next step forward, and that has been hampered to a large degree.” (Interviewee 7)

The introduction of IPRs in the Canadian canola industry has led to difficulties in research that have been identified by the breeders. The range of difficulties include slow flow of knowledge, the use of strategic restrictions on licensing, high transaction costs and uncertainty regarding future research due to the existence of submarine patents. The consequences of these difficulties concern the quantity and quality of the research output. Time losses and cancelled projects are the most obvious consequences and concern the quantity of the research produced. However, there may also be impacts on the research’s quality particularly when the best research tools/material is not available.

5.11. Reaction: Development of Platforms

Canola breeders and researchers have recognized the existence of hurdles in gaining access to research material necessary for their research. The magnitude of nuisance ranges from delays of the project schedule to the abandonment of the research effort or the retraction of the new product from the market. The existence of these impediments creates uncertainty with regards to the acquirement of the input research material and the commercialization of the research output. R&D firms often have to negotiate with multiple patent holders who often compete in the same markets, as well as to be vigilant on new and old patents that can emerge and stall the research or, even worse, the commercialization of a new product. To address the uncertainty related to the acquirement of proprietary knowledge, R&D organizations have undertaken several strategies. Some of them (collaborations, inventing around) have already been examined and we have seen that they do not function ideally; each of them has both advantages and disadvantages. The strategy that R&D institutions seem to have largely implemented to avoid IPR impediments is the creation of platform technologies, technologies that can be used to facilitate a broad range of application based activities. Unlike with other technologies, platform technologies endow researchers with freedom to operate in research areas, avoiding the menace of submarine patents. The importance of freedom to operate issue to plant breeders and their preference in using in-house material is depicted in the following quotes:

"Freedom to operate is one of the problems that anybody faces. There are lots of reasons why you cannot operate. There are lots of ways a patent holder can prevent you from accessing the use of their patent, the royalty maybe too high, the cost of negotiation maybe out of reach for a small operator etc. Usually this is not the case with plant breeding, however negotiating parties can have conflicting agendas, that is one of them, and the owner of the tool may be unwilling to share the tool. They want to hold on to everything they got." (Interviewee 7)

"I am very careful not to accept things from people other than the people who developed them. So if there are IP considerations we invariably sign a MTA to receive things in the first place. The only time that I am really worried about IP in terms of freedom to operate is where I think that I can see something that can lead to a product. And then I think the freedom to operate becomes a very serious consideration when you are thinking about a company commercializing something." (Interviewee 17)
"It is better to have freedom to operate with respect to the project technology to begin with, but sometimes that is really not practical. And I think often we worry about it too

much. I wish I could put that energy into finding industrial partners who can just work out the value of IP and pay for it." (Interviewee 8)

Interviewer: "Why did you increase your protection?"
Breeder: "Primarily is a defensive response to make sure we have freedom to operate. We are not very concerned about R&D expenditures, is primarily to secure freedom to operate." (Interviewee 1)

"…but as long as we have something patentable we will try to patent to make sure that we will have freedom to operate and that we have something to trade." (Interviewee 6)

Interviewer: "Has your protection of research tools increased over the last 5-10 years?
Breeder: "Yes, absolutely."
Interviewee: "Why did you increase protection?"
Breeder: "The business office wanted it to ensure freedom to operate." (Interviewee 13)

"We use research tools that are common knowledge. We don't get material for which we need MTAs. We have material that people come to us and want to use it. We have MTAs prepared for that material. We never bring material to the building here to work on or to work with." (Interviewee 23)

"…we never try to get into areas where we have to acquire IP. We don't want to depend on a particular source of germplasm that is owned by other firm." (Interviewee 2)

Interviewer: "By defensive patenting, do you mean that your first priority is to ensure freedom to operate?"
Breeder: "Yes. That is what we are after. We want to make sure that we can continue research and therefore and therefore by patenting that area we can continue on research and we have the ability to further the work we are doing or to have it commercialized. That is why we look in patenting. It is not to gain any other advantage…what we are after is that somebody else can't put stop to research because if we were to invest so

much time and money to an area of research, we want to make sure that it can be used for the benefit of Canada." (Interviewee 10)

Breeder: "There are lots of reasons why we are undertaking intellectual property protection. One is to ensure we have freedom to operate with respect to our own research." (Interviewee 4)

The quotes presented above provide evidence that R&D firms strategically choose to use germplasm and research material developed within the firm. By doing so, the tragedy of the anticommons is being avoided as there is no need for the firms to acquire multiple technological pieces. Of course, total independence in the conducting of science is difficult if not impossible to achieve. Knowledge builds upon previous knowledge and permission may be required to use this knowledge. Thus, research firms (public and private) in canola breeding are keen on opening new research areas where there is no prior knowledge and hence no patent owners to deal with.

5.12. Summary

Twelve interviewees participated in the survey regarding IPRs in canola breeding. Interviewees possess diverse characteristics regarding the type of research they undertake, the projects and their funding. However, they share a common feature; they have experienced two different regimes, one with no IPRs and one with IPRs in place. Interviewees verified that the canola sector has seen an increased use of patents and PBRs that protect intellectual property from potential infringers. This experience allows the interviewees to speak informatively about the impact of the change in IPRs. As canola breeders change from patenting to publishing, the amount of research output that is available to the research community diminishes. Even though patents can be licensed for a price, there are substantial transaction costs involved, rendering licensing in some cases prohibitively expensive. As the data indicate, the research exemption provided by the Canadian Patent Act does not have wide application as the majority of public and private research targets commercial applications. Lastly, the flow of current material and knowledge is hampered by researchers' unwillingness to share their results with other researchers. To a large degree, this unwillingness is due to the strategic situation faced by the researchers' employers; competition in R&D is fierce and any leakage of information by one company may put at risk its innovative effort and investments.

There are various ways through which proprietary research can be accessed. Collaborations is the most common example, as two parties with complementary IP find it more cost efficient to collaborate rather than license each other's technology. However, due to the proprietary nature of the research resulting from the collaborations, the problem of access is not solved but rather is postponed for the future. Inventing around a technology is another way by which R&D firms avoid patents. The drawbacks of this method are the high cost and the reduced motive for the breeders. Lastly, infringement is rarely used by R&D firms as it involves a high risk and cost.

Blocked access to important technologies and the lack of alternative means to overcome this hurdle appear to be causing difficulties in canola breeding research. These difficulties include delays, cancellation of projects or a lack of participation in research areas where proprietary knowledge exists. Thus, freedom to operate in canola breeding is of importance to R&D firms and is something that R&D policies should take into account.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

The assignment of intellectual property rights in the canola industry in the latter part of the 20th century brought about significant changes in the structure and development of the canola industry. IPRs induced significant private investment in the sector and led to the development of a large number of new varieties. At the same time, although there is little evidence available specifically for canola, arguments were being put forward (e.g. Heller and Eisenberg, 1998) to suggest that enhanced IPRs might have negative effects on R&D through high transaction costs, increased secrecy among researchers and reduced sharing of information. The purpose of this thesis was to explore this last question by conducting a survey of canola breeders.

This chapter begins with a summary of IPRs' negative impact on R&D. The research environment in the last 20-30 years in the canola sector is characterized by increasing patenting activity. As public and private research firms protect their intellectual products, several hold-ups appear as a result of this activity. All these hurdles share a common effect, namely that of blocked access to research tools necessary for further research. The chapter continues with a description of the major forms of reaction against the observed intellectual property protectionism. R&D firms have come up with various strategies to ensure freedom to operate. Lastly, recommendations for further research are discussed regarding the role of the public sector in the canola sector, the winners and the losers associated with increased IP protection and the evolving structure of the canola industry.

6.2. IPRs' negative impact on R&D

The data presented in Chapter 5 indicate that IP protection appears to create difficulties for canola breeders in conducting their research. These difficulties are illustrated and summarized in figure 6.1. Specifically, the evidence collected from the interviews indicate that increased IP activity in the canola sector during the last 20 to 30 years has reduced the sharing of knowledge-information among breeders, increased transaction costs and negatively affected the research material that is publicly available. Secrecy has reduced the flow of information among breeders and research institutions, while there is an indication that sharing of research material follows the same trend. Canola breeders appear to be unwilling to disclose their inventions, at least not before patenting has taken place.

The new regime established with the arrival of IPRs requires that most transactions take place among institutions rather than among breeders. The consequence of this change is reduced access to current material and ongoing research that could potentially enrich or complement other research efforts. An additional element that ensues from institutions' elevation to main players in material exchange is the formalization of the transactions. Arrangements across organizations are carried out mainly through negotiations, an expensive process both in terms of time and money. These costs add to the increased transaction costs related with the management and operation of IPRs. Therefore, transactions like licensing and trade of patents are encumbered by additional costs, rendering access to proprietary material expensive and difficult to occur.

With respect to publicly available material it seems that it is "drying out" as organizations prefer patenting over publishing to ensure freedom to operate. Of course patenting itself is a way of publishing as it involves a description of the new invention; however a patent means that the use and exploitation of the revealed information in research with commercial purposes is prohibited. Thereby, the trend of increasing patenting leaves the research community with less available research material to work with, confining the opportunities for research.

The interviews also suggested that plant breeders were using a number of strategies to minimize the impact of these difficulties. Collaborative activity and inventing around are ways that could potentially alleviate the problem of blocked access to research material, but there are limits to what they can accomplish. Collaborations that are formed in the canola industry mainly involve public and private institutions. This has an impact on the availability of the research output produced from the partnership. Private firms seek ownership of the produced technology thereby putting constraints on those wishing to access it. To the extent that the knowledge produced by partnerships becomes proprietary, collaborations create the tragedy of the anticommons anew. Inventing around, although appealing for R&D firms that look to overcome a particular patent, is a risky venture and requires a large amount of resources. Moreover, inventing around existing technologies provide small, if any, motives to researchers.

Research tools can be viewed as the sum of current, proprietary and free material. Blocked access to research tools has been identified as taking place in each of these three categories and in aggregate. Secrecy and reduced sharing block access to current material, while limited applicability of research exemption and high transaction costs deters access to proprietary material. The clear preference of patenting over publishing blocks access to free or public material as the public pool of knowledge is shrinking. Lack of access to current, proprietary and free material causes difficulties in R&D since they are used as inputs for the creation and production of new technologies and products. At the aggregate level, the lack of access to research material is verified by the inadequacy of methods used to overcome IP barriers, such as collaboration and inventing around. Hence, as the figure 6.1 illustrates, the blocked access to research materials, combined with insufficient alternatives leads to difficulties with R&D such as delays or abandonment of research efforts.

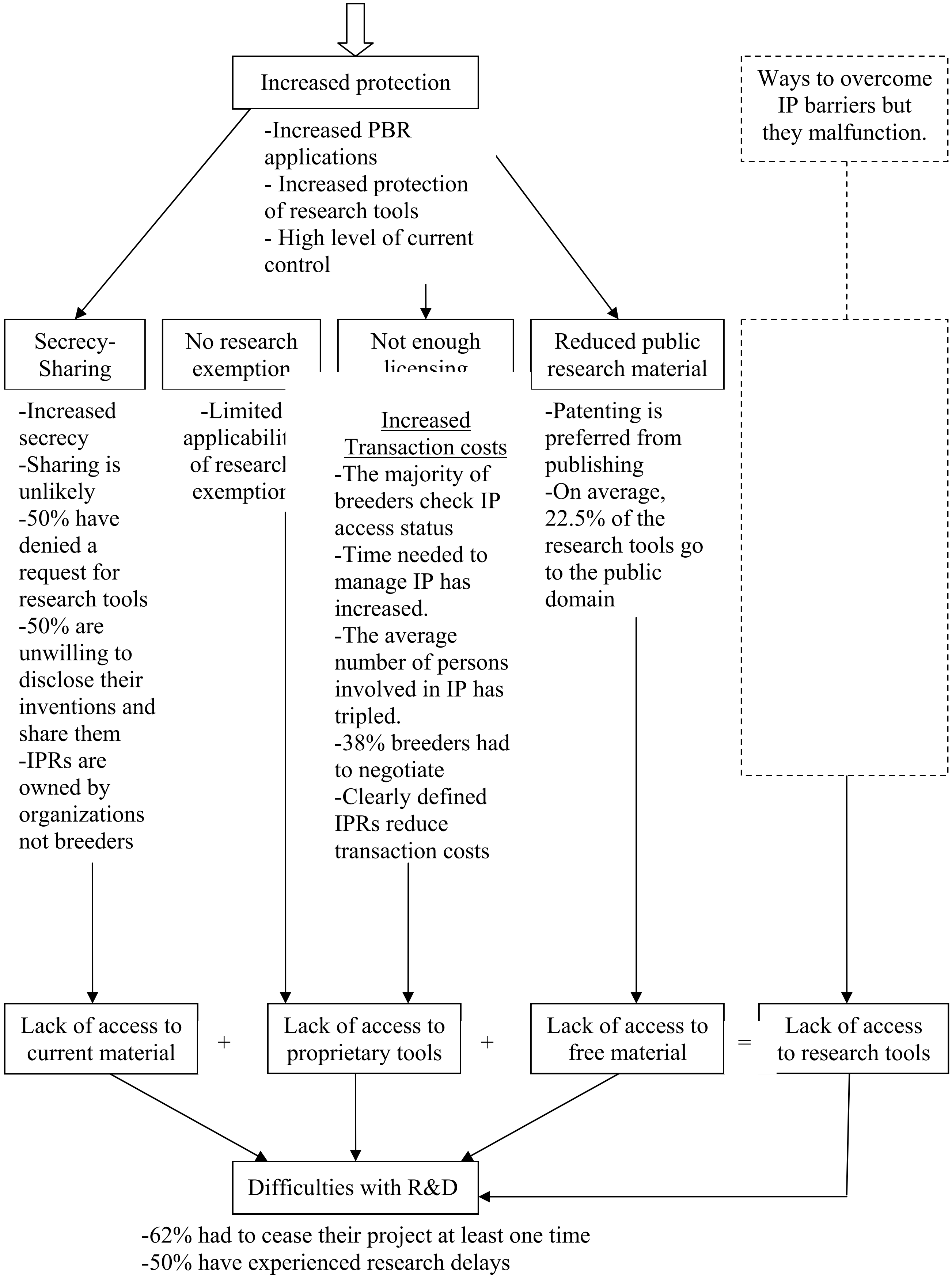

Figure 6.1. **IPRs' interference with R&D.**

6.3. Change of behavior

The application of biotechnology in the canola R&D sector has brought about some important changes, at various levels, in the way research is planned and implemented by research institutions. As the review of the literature indicated, owners of IP have an incentive to overcharge those that wish to license the technologies (Buchanan and Yoon, 2000) creating the tragedy of the anticommons (Heller and Eisenberg, 1998). As the data from the survey indicate, the freedom to operate issue is important to public and private organizations.

Not surprisingly, the research community has introduced strategies by which the tragedy of the anticommons can be addressed. One strategy is the development of platform technologies, technologies with broad use that endow researchers with multiple research paths. Once a platform technology has been developed, other applications may take place upon that technology, allowing the continuation of research without the need to obtain licenses. A similar strategy that is often employed is the development of varieties using in-house material, thus eliminating the need for and the dependence on other R&D organizations. Some breeders reported that they do not use material from other organizations as this would render their current and future innovation dependent on the licensed material.

A second strategy in avoiding the tragedy of the anticommons is collaboration. When two or more R&D organizations possess complementary technologies, then research collaboration among the firms can avoid the need for each of them to pay the others for licenses. In canola research, the collaborations formed among research partners overcome the tragedy of the anticommons only to the extent that the research output is published. If, however, all or part of the research product becomes proprietary, the tragedy of the anticommons is postponed as those needing the proprietary technology in the future will have to obtain a license. Inventing around completes the set of strategies R&D firms currently use to succeed freedom to operate, even though this strategy is seldom used.

Given the various ways employed by public and private firms to ensure freedom to operate, the tragedy of the anticommons effects may not be obvious. The fact that

R&D organizations continue to produce research, sometimes at an increasing rate, does not negate or disprove the tragedy of anticommons. R&D firms are observed to find new ways (creating technological platforms, collaborate, invent around) to ensure access to critical material/research tools, thereby partly alleviating the tragedy of the anticommons problem. Comments by canola breeders indicate that there are still obstacles (tedious negotiations, secrecy among researchers) that block access to research material. In addition, transaction costs, both in terms of money and time, appear to be important in slowing down the exchange of research material.

6.4. Genomics and FTO

Genomics have become an integral part of plant breeding. The systematic study of a plant's genome and more specifically the identification of a gene's function and its linkage to specific traits (also known as functional genomics) has opened new roads for plant breeding and crop improvement. By understanding why certain traits are expressed, which sets of genes are specifically responsible for that expression and under what conditions, scientists are able to create varieties with exact combinations of traits (CIMMYT, 2000). Genomics and its tools have helped plant genetic researchers to work faster and more precisely.

The federal government has recognized the necessity of genomics in plant breeding and has responded to this need by establishing genome centers throughout Canada. These centers provide a range of platform services such as custom microarray gene expression, DNA mapping and DNA sequencing (Genome Canada, 2007). In addition to these research centers, the federal government has initiated genomic research within federal labs such as the AAFC and NRC. The purpose of these projects is to bring genomics and its tools at the aim of plant breeding for the development of enhanced products with specific traits. As *Raine et al.* 2007 have indicated, "no new research project of any scale involving plant breeding takes place without genomics support"(Plant Agriculture Genomics Group, 2007).

The increasing appliance of genomics in plant breeding is expected to render the freedom to operate issue more acute in the forthcoming years. If a single gene or a group of genes with certain traits can be patented by private R&D firms, the licensing of these traits to third parties (e.g. other labs) will be hindered. The owner of a key trait or an enabling technology is automatically placed in a strong bargaining position with respect to potential buyers, leading to the hold up problem. Things become more complicated when several companies possess different genes, the combination of which expresses a single plant characteristic. In these cases, there could very easily be a tragedy of the anticommons problem, the consequences of which will be the forgoing of the exploitation of the trait unless the actions are taken.

To ensure freedom to operate, R&D firms are developing platform technologies. The development of these technologies is a strong indication that the primary and long run objective is autonomy in R&D. There is an obvious trend by the R&D firms to reduce their dependence on foreign proprietary knowledge and increase their own research resources. The adoption of this strategy reduces the risk that an R&D firm runs of stumbling on a "submarine" patent and having to negotiate with third parties after having incurred sunk costs. Competition is one reason for this behaviour; R&D firms are reluctant in giving away any kind of information that would allow competitors to get involved in the same research area. The threat of having something patented by a foreign firm is another reason; some companies may look through some published data and file a patent on the information if it could have commercial value or impact to the company.

When freedom to operate (FTO) in a research area cannot be ensured by the R&D firm (e.g., when there is already proprietary knowledge in that area), FTO will have to be secured by using different means. Collaborations is the most prominent one. As the data from the interviews indicate collaborations are strategically used to gain access to certain research tools or germplasm material. Normally, collaborators share access to each others technologies for the sake of mutually developing an improved technology or a product that has commercial value. Examples of collaborations can be found in some of the largest biotech firms worldwide, like Monsanto, Dow and BASF. Monsanto and BASF have engaged in a long-term collaboration for the development of high yielding crops and crops that are more tolerant to environmental stresses such as droughts (BASF, 2007). Dow and Monsanto have agreed to share herbicide tolerance and insect-protection genes for the joint development of a new corn variety, SmartStax™ (Food Navigator, 2007). Therefore, when FTO becomes an issue, R&D

firms engage in collaborations that allow them conditional access to the desirable technologies.

The freedom to operate problem will have further impacts on the structure of the industry and the ability of new firms to enter the market. The companies that first patent an important plant attribute (e.g. a gene resistant to a specific pest) have a comparative advantage over the newly established R&D firms. In order for the entrant firms to be competitive, they will have to acquire certain technologies or genes that have been patented, bringing dominant firms in a strong bargaining position. As Fulton and Giannakas (2001) have indicated, one remedy to such problems is mergers and acquisitions. In other words, the dominant firm will occasionally buy small start-ups that can develop a promising technology but lack the capacity and the resources to actually develop that technology and transform it to a product. There is indication that this is the case in the biotech industry. According to the World Development Report (WDR) 2008, the market share in 1997 for the four largest agrochemical and seed companies was 33% for agrochemicals and 23% for seeds while in 2004 the concentration ratio of the top four companies (CR4) increased to 60% and 33% respectively. With respect to biotechnology patents that were issued in the US, the CR4 was 38% in 2004 (WDR, 2008). Given the fact that the industry is already concentrated, genomics along with gene patenting are expected to consolidate the industry further.

6.5. Recommendations for Further Research

The tragedy of the anticommons and the pyramid framework are ways to identify and explain the adverse impacts of IPRs on R&D. The interview responses support the view that access to foreign material/research tools has deteriorated in the past 20 to 30 years.

In chapter 3, it was shown that the optimum level of IPR strength that maximizes the net R&D output depends on the relative magnitude of the positive and negative effects (or the incentives and the disincentives) that the extension of IPRs have on R&D. Due to insufficient data regarding the exact shape of the incentive and the disincentive curves, three cases were looked, the interior solution and two corner solutions. From this examination, no single policy implication regarding the optimum level of IPR strength arose. The interior solution calls for a modest level of IPR strength while the corner solutions call for a maximum or minimum IPR strength. Future research on measuring the gains and losses accruing from additional extension in IPRs would throw light on decision making regarding the optimum scope and length of patents. The tuning of these parameters determines the amount of research produced in a society; hence a framework that would provide information regarding their impact on R&D needs to be developed. This information could then be incorporated into a wider cost-benefit analysis regarding the impact of IPRs on society's welfare.

Theory and empirical data presented in this thesis indicate that the biotechnology industry is dominated by few large firms. Also, the merges and acquisitions as well as the multi-billion dollar collaborations that are taking place among the large firms are expected to consolidate the industry further. One remedy to this problem would be the intervention of the public sector. The intervention could take the form of new legislation regarding IPRs towards a looser regime or a more intense involvement of the public sector in the production of R&D output. In the second case, the production and dissemination of publicly available knowledge is expected to encourage new firms to develop their own technological platforms. The barriers to entry for the new R&D firms decrease, as more technological building blocks are available for use. An increase in the number of firms in the biotech industry would encourage competition and spread the generation of knowledge over a larger number of public and private institutions.

If the public component of the plant breeding sector is to undertake initiatives in producing R&D, then an unhampered transfer of knowledge among public institutions is necessary. Cooperation is highly recommended, particularly when complement technologies are owned by different actors. The need for closer cooperation among public institutions becomes more apparent when it is observed that public research organizations are increasingly deciding to create technological platforms and to preserve knowledge within their organization.

Given this background, the examination of possible organizational schemes among the public institutions across Canada, as well as the measurement of the benefits accruing from such ventures, could be the subject of further research. Moreover, additional questions arise as to the impact of collaborative activity on the public pool of knowledge – i.e. would the collaborations produce proprietary or free knowledge? It is clear that the structure and function of the public institutions requires further investigation to determine the set of changes needed to render public sector inviter of future research.

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APPENDIX A: QUESTIONNAIRE FOR CANOLA BREEDERS

Questionaire for
Emmanouil Oikonomou's M.Sc. Thesis.

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____________%
Please, specify what type of applied research you do

Development _____________%
Development includes variety development, commercial development, germplasm 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, germplasm, 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. WE WOULD LIKE TO UNDERSTAND THE EXTENT AT WHICH THE INVENTIONS IN PLANT BREEDING ARE PROTECTED BY INTELLECTUAL PROPERTY RIGHTS

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

- o The institution owns it
- o The researcher owns it
- o Joint ownership: the institution and the researcher
- o The funding organization owns it
- o 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?

- o Trade secrets
- o Patents
- o PBRs
- o Genetic fingerprinting

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

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

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

_______________%

15. Has the number of applications for plant breeder's rights by you increased 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

  ____

  strongly agree strongly disagree

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

  ____

  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

  ____

  strongly agree strongly disagree

- o You always enforce your patents/PBRs, etc. against universities

  ____

  strongly agree strongly disagree

  ☐ Never enforce

- o You always enforce your patents/PBRs, etc. against industry

  ____

  strongly agree strongly disagree

  ☐ Never enforce

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

- o YES
- o NO

19. Why did you increase your protection?

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

PART 3. CONTRACTS AND COLLABORATIVE ACTIVITY

20. Do you collaborate with other researchers?

	Private sector	Public sector
Proportion of cases where you collaborate with:		
OF WHICH You collaborate formally		
OF WHICH You collaborate informally		
No collaboration		

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 funding ________________%
- 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	
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?

- o YES
- o NO
- o 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:

- o Never
- o In ________% of the cases
- o Always

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

- o Always
- o In_____________% of the cases
- o Never

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

- o YES
- o NO (skip to 32)

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 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.

____

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?

- o YES
- o NO

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

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

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

____

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

  ____
  Very unlikely very likely

  ☐ Uncertain

- ✓ Universities

  ____
  Very unlikely very likely

  ☐ Uncertain

- ✓ Private industry

  ____
  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?
   - Yes, it significantly increased
   - Yes, it somewhat increased
   - No

h) How many programs suffered research delays because of the difficulties in obtaining IPRs?

___________ out of total ___________ programs

i) What was the maximum delay that you experienced in obtaining IPRs?

________________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.]

   - Yes, please specify

   - No

b) Have there been any instances where clearly defined IP rights sped up the time the research took?

   - Yes, please specify

   - No

c) Are there any instances where IP rights increased your ability to invent/work around?

   - Yes, please specify

   - 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?

- money incentives (profit)
- recognition
- ownership
- trading chip
- source of financing for your research
- other, please specify

Researcher	Institution	Program
cdn $	cdn$	cdn $

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?

-THE END-

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: Emmanouil Oikonomou (name)

306.966.4046 (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 and Mr. Emmanouil Oikonomou's thesis requirement for a PhD and MSc 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 and Mr. Oikonomou 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 and Mr. Oikonomou will try to ensure that your identity is protected in the ways described below. If for some reason Ms. Galushko and Mr. Oikonomou 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 and by Mr. Emmanouil Oikonomou 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, Dr. Fulton, Mr. Oikonomou 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 13th 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: 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

Emmanouil Oikonomou (Researcher)
Graduate Student, Department of Agricultural Economics
University of Saskatchewan
306.966.4046