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Chapter 30

The Public and Not-for-Profit Sectors in a Biotechnology-Based, Privatizing World: The Canola Case

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Introduction

The development of the canola sector in Canada is an excellent example of the impact of institutions on the development of an industry. Public and private research, combined with a number of institutional innovations, have transformed rapeseed from a marginal crop used as an industrial lubricant into the third largest edible oil crop in the world.

Neoclassical economic theory would suggest that with full allocation of property rights, optimal development of the canola market would be forthcoming from private initiative. The canola story shows otherwise. Even after the public sector developed the base germplasm for the industry, a number of key elements required to develop the market—including continuing research, market development and extension services—were not automatically forthcoming. Each of those factors exhibited high asset specificity (e.g. there was little or no value from alternative uses), low rivalry and low excludability. In short, no single actors would invest to develop the product or market further because they had little or no expectation that they could recoup adequate revenues to pay for their investments. The canola story highlights the role of institutions in overcoming these market failures.

This study uses the new institutional economics (NIE) framework to interpret the evolution of institutional and contractual arrangements that have successfully governed the development of the canola industry. A variety of new institutions have been created to address and resolve many of the market failures associated with industry development. The failure to develop the appropriate institutions to address industry development problems can lead to either underperformance or the complete elimination of an industry. In the case of canola the changes in research institutions allowed the industry to successfully overcome significant obstacles.

For the purposes of this discussion, the development of the canola industry can be broken into two main periods: pre-biotechnology and biotechnology. The first period began in the immediate post-war period as the Canadian public sector undertook a sustained effort to develop a domestic edible oil source, using rapeseed as the base. This effort spanned more than 40 years of public research and development, combined with one key institutional innovation: the creation of an industry-funded and -managed association to coordinate research, undertake farmer extension and lead market

development efforts. During this time canola was widely adopted by producers and became the second most valuable crop in Western Canada.

TABLE 1 Investment in Canola Research, by Funding Source, Selected Periods

	1944-85	1986-98
Public	68%	41%
Private	30%	57%
Association	2%	2%
Global annual industry investment (1998$)		
Average	$20 million	$85 million
Low	$3 million	$51 million
High	$43 million	$128 million
Source: Authors' calculations from the Canola Research Survey 1997.		

Since 1985, research in the canola industry has become dominated by large private firms employing biotechnology to produce genetically superior products. Although the new biotechnologies were ideally suited to canola, both shortening the innovation cycle and enabling more selective targeting of new traits for development, it was not at all certain that the new tools would be applied to canola in Canada. The large private research investments into canola research were ultimately attracted by extension of intellectual property rights to both seeds and genetic material, by the development of a responsive regulatory system and by a shift in public effort to support private research. The private sector presence grew to almost 60% of the total investment, which resulted in control of approximately 85% of the resulting varieties and more than 80% of the new technologies.

This paper uses the new institutional economics approach to compare and contrast the two periods and to show the importance of institutions in resolving market failures and hold-ups. The next section outlines the analytical framework for examining the development of canola. The paper then examines in some detail the institutional story of canola, highlighting instances of market failure and the role of institutions in resolving those problems. The final section is a summary and discussion of some of the implications of this study for other industries undergoing technological change due to the introduction of biotechnology.

The Analytical Framework

The new institutional economics (NIE) deals with the economics of institutions and institutional change. Unlike traditional theory, NIE pays attention to the determinants and the evolution of different institutions and contracts over time. According to Jacquemin (1987), "hierarchies, federations of firms, and markets compete with each other to provide coordination, allocation and monitoring. It is only when one organiza-

tional form promises for specific activities a higher net return than alternative institutional arrangements that it will survive in the long run."

The focus of this approach is thus on the costs of alternative types of transactions. Williamson (1979) argues that "if transaction costs are negligible the organization of economic activity is irrelevant, since any advantages one mode of organization appears to hold over another will simply be eliminated by costless contracting." Transactions are seldom cost-free. Dahlman (1979) identifies three specific cost components: search costs incurred locating those whose reciprocal interests make likely candidates for a transaction; negotiation costs in reaching an agreement on the terms of exchange; and enforcement costs as one monitors the performance of the parties to the transaction, in light of their contractual obligations. These three cost components are routinely classified as either *ex ante* (before contracting) or *ex post* (after contracting) costs, according to the contract's date of agreement.

Williamson (1979) identifies three principal dimensions in which transactions may differ from one another, defined as uncertainty, frequency, and asset specificity. Uncertainty, in the sense intended by Williamson, is considered to come from behavioral risk (i.e. opportunistic behavior) rather than event-oriented risk. The second quality of a transaction that bears on its cost is the frequency with which it recurs: occasional transactions generally use general-purpose governance structures as it is costly to put specialized mechanisms into place while recurring transaction, by their nature, are suited to either short- or long-term contracts. Finally, asset specificity refers to investments that have a lower value in an alternative transaction, i.e. the opportunity cost of a particular transaction is much lower in its best alternative use when the original transaction is terminated.

In a competitive marketplace made up of many informed buyers and sellers, market exchange is an institution that effectively governs the production and consumption of goods and services. The prices generated in a market create Adam Smith's 'invisible hand' to match the marginal cost of providing a good to the marginal value of that good to society. In a great many instances in the market place, a simple exchange of goods and services at an agreed upon price is a low-cost transaction that provides the correct incentives for the buyer and sellers. When the marketplace fails to operate in a manner such that the marginal social benefit is not equal to the marginal social cost of the transaction, then a market failure is said to exist.

Those market failures from standard economic theory most relevant to this study are associated with public goods, common pool resources and technical externalities. Markets fail to provide adequate public goods because no one can be excluded from their consumption and, hence, there are no feasible means for a firm to charge the users for the provision of the goods. Common pool resources also suffer from the lack of exclusion, in that the resource is "subtractable" or rival and overuse can result in the depredation of the resource. Both positive and negative technical externalities, such as knowledge or pollution, also represent market failures because they are unpriced in the market. The key factor in each of the market failures is the lack of marginal cost pricing, often due is

the inability of producers to exclude consumers from using their good without paying the price.

One market failure that has recently attracted attention in the investment literature is referred to as the hold-up problem. Milgrom and Roberts (1992) define it as "the general business problem in which each party to a contract worries about being forced to accept disadvantageous terms later, after it has sunk an investment or worries that its investment may be devalued by the actions of others." The hold-up problem may be induced by other forms of market failure but deals most specifically with the investment decision. Because the hold-up problem often prevents otherwise advantageous investment it can create a real obstacle to industry development.

There is a relationship between the presence of transaction-specific and asset-specific investments and the potential for *ex post* hold-up (Williamson 1983). With asset-specific (specialized) investments, the value of the asset in its specific use is far greater than its value in the next-best use. In order for the initial specific investment to be undertaken the real rents to each party (returns in excess of *ex ante* investment) must not be negative. However, when one party's *ex post* opportunity cost is reduced to the initial investment, its bargaining power is also reduced, and it is less likely for this party to cover the initial investment. This party will recognize the potential for *ex post* hold-up and therefore will be unwilling to incur the *ex ante* investment cost. Hence, if the initial investment is large relative to the respective *ex post* opportunity cost, the initial investment will not be undertaken by that party and market failure will occur since the specific transaction is Pareto superior to all alternative transactions.

Institutions evolve to overcome market failures. North (1991) defines institutions as a set of rules, both formal (e.g., statues) and informal (e.g., norms), that constrain the behavioral relationship among individuals or groups. Institutions are effective rules, not nominal rules, with an emphasis on enforcement (Eggertsson 1994). They can be established, enforced and policed, either by an external authority or by voluntary acceptance. They are predictable, stable, and applicable in situations that are repetitive. Institutions define the decision-makers' utility choice set and their structure of incentives.

There are several forms of private, public and collective action that can address market failures. Williamson (1983) suggested common ownership (e.g. vertical integration) as a response to asset specificity. Klein and Crawford (1978) observe that "integration by common or joint ownership is more likely the higher the appropriable specialized quasi rents[2] of the assets involved." Williamson (1983) argues, alternatively, that the potentially opportunistic party could make an *ex ante* credible commitment to the exchange; this commitment usually takes the form of partial redistribution of specific investment costs by the potentially opportunistic party. Joskow (1987) states that, with many types of asset-specific investments, long-term explicit contracts can reduce the potential for *ex post* hold-up. Coase (1960) argues that governments can play the role of supra-firms by producing public goods and addressing externalities through taxation, subsidization or regulation; in some circumstances, government institutions may be the most effective or lowest cost means of addressing market failures. Finally, Coase (1960)

suggests collective institutions (sometimes referred to as non-government organizations or the participation sector) may often be more effective than government.

Particular institutions tend to be best suited to govern particular types of transactions. Picciotto (1995) classifies institutions into three general types—hierarchy or the government sector; the private sector; and the participatory sector. The government sector is best at producing public goods (e.g., defense or justice) that are consumed by all citizens but where the voice of special interest groups is not important. Public goods are characterized by low excludability and low subtractability (rivalry), which make privatization not feasible. The private sector tends to dominate whenever property rights can be assigned to make the goods excludable and the goods produced are subtractable. Although the property of exclusion allows the producers of the good to sell at the marginal cost of production, it may not always be a sufficient condition for a good belonging in the private sector—a good with low subtractability, for example, exhibits economies of size, tending to a natural monopoly, which creates the potential need for government intervention. The participation sector is best at governing common pool goods (e.g., market development services) or public goods where voice is important (e.g. coordination). These goods are generally not excludable, which prevents them from becoming private goods, but their benefits are often restricted to a specific group who are in the position to use the goods. In this case, it is in the common interest of the group to manage the good to their mutual benefit. It is also often the case that the group has more of the information required to manage the resource, making voice important.

This framework is used in this paper to evaluate the changes in the canola industry, focusing primarily on the institutions that evolved to resolve market failures and hold-ups.

The Institutional Story of Canola

The institutional story of canola development spans two distinct periods. Over time, institutional arrangements have evolved to address specific issues and situations that impeded the development of the market for canola.

Pre-biotechnology: 1944–1985

During World War II the rapid increase in the use of steam power created a strong industrial demand for rapeseed oil due to its lubricant properties (White 1974) and rapeseed was grown in commercial quantities for the first time in Canada. A small portion of the rapeseed oil was refined for human consumption. In the immediate post-war period production and usage of rapeseed dropped sharply. With no legally sanctioned property rights for seeds or other germplasm and no effective hybrid systems, rapeseed held little appeal to private seed companies.

Interest in rapeseed languished until the 1950s, when Agriculture Canada researchers identified a need for a new oilseed that could both provide an alternate to wheat in Prairie agriculture and could meet domestic needs for edible oils (Downey and Robbelen 1989). A small but significant research program at Agriculture Canada and the National Research Council began, focused initially on processing innovations and agronomic improvement in the crop.

In the mid-1950s rapeseed oil was reintroduced as an edible oil but quickly was under attack. In 1956, K. Carroll, Department of Medical Research, University of Western Ontario, presented evidence that the consumption of rapeseed oil resulted in reduced weight gain, fatty heart, increased cholesterol content and increased weight of adrenal glands in rats (Sauer and Kramer 1983). Additionally, the high levels of glucosinolates in rapeseed meal were found to cause metabolic upset and lower feed-to-weight-gain ratios in non-ruminant animals (Blakely and Anderson 1948; Bell 1955). As a result of this evidence, there was a short-term ban in 1956 on the use of rapeseed oil for edible purposes. Although the ban was almost immediately lifted, plant breeders responded to these early concerns, redirected their research to lowering the levels of those two elements and by 1963 had isolated rapeseed germplasm that was low in erucic acid and other germplasm low in glucosinolates.

During this early period rapeseed was not established as an economic product and almost all its attributes were unknown. There were no significant quantifiable returns to research to be captured by a research effort, which made it impossible to justify private research investment. Apart from a continuing breeding program by Svalof in Sweden, the public sector in Canada was almost the only institution willing to fund basic rapeseed research. It contributed more than 68% of the total research investment (see Table 1).

With most of the research effort being conducted by the public sector, information, including genetic information (germplasm) about the seed and technologies, moved relatively freely between participants. All information derived from the research effort was readily shared within the industry. The researchers in various disciplines examined problems and worked collectively toward solutions. New technologies and new varieties were released for use without any restrictions. The outcome of this situation was that the research was a public good and the returns to the research investment were widely dispersed among growers, processors and consumers.

The late 1960s brought a fundamental change in the development of the rapeseed/canola industry. By this time rapeseed production had grown to several thousand tonnes and the vegetable oil market had grown. It was clear that there was potential for rapeseed producers and rapeseed processors to economically benefit from further development. But more investment in both product development and in market structures (e.g. extension, foreign market development) was required to secure the development of the industry.

Almost simultaneously, all parts of the industry realized the potential of the crop and the need for some central body to work for the development and betterment of the

rapeseed industry. There was no established economic product, no known market, no identifiable product attributes and no effective private property rights in the industry. Furthermore, no one institution (public or private) or individual had the means or incentive to undertake development work alone due to the relative non-excludability of the market structures. A new institutional arrangement was needed.

The Rapeseed Association of Canada emerged in 1967 as a not-for-profit association of groups that had a stake in the Canadian rapeseed industry. The initial 30-member Board represented 12 industry groups. At the beginning, 70% of the Association's budget came from crushers and exporters through a voluntary $0.50 per tonne levy on rapeseed exports and seed crushed domestically. The government offered only a little support initially but within a short period of time contributed almost half of the Association's resources.

Although the Association never contributed more than 5% of the total annual research budget for the industry, over the years it evolved to set the research direction for the entire industry and coordinated the research activities. It did not do any of its own research; rather it allocated funding to support existing research groups; in that way it leverage both public and private funds in support of research and development in the interests of the entire industry. In the early years, the Association devoted the majority of its resources and effort into research that could resolve the problem of high erucic acid and glucosinolate content. By 1968, researchers at Agriculture Canada and the University of Manitoba had bred Oro, the first low erucic acid *b.napus* variety; in 1971, Span, the first low erucic acid *b. rapa* variety was released. A major watershed in the industry came during this period, when plant breeders succeeded in producing varieties with both low erucic acid and low glucosinolates: Tower was the first double-zero *b.napus* variety in 1974 and Candle became the first double-zero *b.rapa* variety in 1978.

With the final piece of the breeding puzzle now in place, the roles of both the public research community and the Association Council began to shift. Although public research groups continued to work to lower the levels of erucic acid and glucosinolates, the push was on to improve the yields and extend the effective planting range for canola. From the Association's perspective, with double-zero rapeseed now available, the biggest challenge was to increase both the production and market for the new product. Further investment in research and infrastructure required a greater flow of product, which was in everyone's best interests, but impossible for anyone to pursue individually. Corporate sponsorship of Association research began during the period.

The task was not going to be easy. Long-term health studies between 1956 and 1970 continued to raise health concerns about rapeseed as an edible oil. These negative findings placed the long-term future of the rapeseed industry in serious doubt. Both the Japanese and European buyers had expressed reservations about consuming Canadian rapeseed after 1970 while the US government had not yet ruled as to whether rapeseed was a safe food. Hence, once the new varieties were developed, the task was to get farmers to switch to the new seeds and to get international markets to buy the new oil.

When the problems identified with high erucic acid rapeseed oil were again highlighted at a 1970 oilseeds conference in St. Adele, Quebec, it became imperative for the Canadian industry to adopt the recently available low-erucic varieties as quickly as possible. Due to the extensive efforts of Agriculture Canada and the Rapeseed Association, the changeover to low-erucic varieties was 86% complete by 1973 and 95% complete by 1974 (National Research Council, 1992). The Association did not engage in actual market transactions or the handling of the product in any way and did not take a position on the marketing system, enabling it to act as a credible voice in the market. Although government extension services played a key role in the effort to change the industry, the Association took the lead in market development, crop production and public relations during the introduction of low-erucic varieties and undeniably was critical to its success. It is highly unlikely that any one participant in the sector would have been able to coordinate the rapeseed research and extension effort necessary to move the industry beyond that critical juncture.

The Rapeseed Association also sought "to explore potential markets and to conduct promotional and servicing activities of any kind conductive to the expansion of markets throughout the world" (Canola Council of Canada, 1995). The Association engaged in a proactive effort to differentiate the new double-zero rapeseed from traditional varieties. In 1978, the Association applied for and received a registered trademark of 'canola' for the new variety (Kneen 1992). The 'canola' trademark was established to represent rapeseed varieties with low erucic acid oil (5% or less) and low glucosinolate content (three milligrams per gram or less). With continuing research through the following eight years, the level of erucic acid and glucosinolates continued to drop. By 1985, five canola varieties were registered and the Trademark Branch of Consumer and Corporation Affairs approved a request to further tighten the quality restrictions on the canola trademark. In 1986, the canola trademark was amended to designate rapeseed varieties with erucic acid less than 2% and glucosinolate content less than 30 micromoles per gram (Kneen 1992). That trademark is protected in other countries through international agreements. For a nominal fee, the Canola Council of Canada will provide a license to use the word "canola" and the stylized flower logo on any packaging of products which meet canola quality standards and fall within logo license content requirements.

On the institutional front, the Rapeseed Association of Canada formally shifted its focus to the new 'canola' product when it changed its name, in 1980, to the Canola Council of Canada. This symbolic move formally acknowledged the development and acceptance of canola varieties. More importantly, the Council began to work with researchers and marketers to position canola as a premium human oil in order to increase the acceptance and potential market of canola oil.

The Council funded extensive research into the health benefits of canola. By 1984, a number of health studies showed that consumption of canola oil, which was low in saturated fatty acids and high in monounsaturated fatty acids, provided significant health benefits when compared with consumption of other fats and oils (Malla, Gray and Stephen 1995). These results, plus longitudinal food safety studies, contributed to the

positive health evidence for canola oil. In 1985, the Canola Council of Canada and Agriculture Canada presented data to the United States Department of Health and Human Services, which ultimately granted canola oil the status of 'generally regarded as safe' (GRAS) in 1985 (US FDA, 1985). This designation opened the way for the increasing privatization of the industry.

Perhaps more important for the long-term development of the industry, the RAC/CCC led the effort to convert rapeseed into a premium edible oil. During this period canola became marketed as a distinctive commodity with desirable attributes that opened markets in the US and worldwide. Furthermore, as a result of RAC/CCC extension efforts, canola became fully accepted as a crop by producers and was grown almost to the maximum that crop rotations would allow. By 1985 approximately 3.5 million tonnes of seed were produced on seven million acres in Western Canada.

The lessons from this period are clear. Unless there is an economic good, with identifiable product attributes that can be valued in end-use markets, there is little chance that private investment will be forthcoming to capture theoretical gains to research, no matter how large they are. In the canola case, it was only after the public sector created an economic good and invested in development that the industry was willing to consider investing. Even then, without private property rights to the results of breeding and with highly uncertain market prospects, research was an almost pure public good, and little private research was forthcoming. Public sector scientists dominated the research effort, both through their investments in capital infrastructure and their human resources engaged in the research effort, and the ownership of the research outcome remained in the public domain. Nevertheless, private capital began to enter the market. The marketers and processors were instrumental in forming the Rapeseed Association of Canada, which increasingly invested through a check-off to focus and co-ordinate public research. In addition, the Association/ Council provided much of the critical extension and market development services that helped to grow the industry and justify further investment; no single actor had the incentive to invest in those activities as the benefits were largely not excludable.

The Biotechnology Phase: 1986-1999

After 1985 research in the canola industry became dominated by private firms employing biotechnology to produce genetically superior products. Several factors attracted the large private research investments into canola research, including: the new biotechnologies themselves; extension of intellectual property rights; development of responsive regulations; a shift in public effort to support private research; and the development of hybrid technologies. These factors all combined to increase the opportunity to capture value from innovation.

New regulatory provisions and assignment of property rights created the conditions for increased private investment. In 1985 the Canadian government modified the Seeds Act to allow varieties to be introduced that were "as good as" reference

varieties; previously new varieties had to prove to be "better than" reference varieties. In addition, the government moved in 1990 to assign private intellectual property rights to germplasm with the adoption of Plant Breeders Rights. Following the negotiation of the International Union for the Protection of New Varieties of Plants (UPOV) in 1978, Canada began to talk domestically about implementing plant breeders' rights, a form of intellectual property rights for the agri-food sector. Although the Canadian Plant Breeders Rights Act was only passed in 1990, the indication of intentions was enough to attract a number of companies to initiate or relocate canola research programs to Canada. This assignment followed a number of milestones, including the US Patent Office decision of 1985 to grant patents for whole plants. Almost every breeder has applied for Plant Breeders Rights for varieties developed after 1990, even though many of the applications are abandoned if the market share for the variety did not justify the effort. In 1997, it was estimated that varieties protected by plant breeders' rights were used on 55% of the total acreage seeded to canola (Phillips, forthcoming).

TABLE 2 Attribution of New Canola Varieties to Public and Private Sector, Selected Time Periods

	1944-85	1986-98
Public	24	27
Private	1	153
Total	25	180
- of which hybrids	0	15
% distribution		
Public	96%	15%
Private	4%	85%
- of which hybrids	0%	8%
Source: Canadian Food Inspection Agency 1998.		

The increase in private research funding was also induced by government subsidies. During the 1990s, the public sector responded to the new biotech environment by redirecting its research effort. The public sector, instead of competing with private breeding programs, shifted its focus to supporting and at times actively encouraging private activity. The federal government refocused much of its effort in Agriculture and Agri-Food Canada (AAFC) and the National Research Council, giving those agencies the mandate and authority to collaborate with and complement private efforts. The AAFC Matching Investment Initiative, for example, redirected some funds that had been previously devoted entirely to public research to encourage and match private research priorities; AAFC matches industry's R&D contributions to collaborative research projects up to a maximum of one-for-one. Meanwhile the provinces and various federal development agencies invested in infrastructure (e.g. Innovation Place), established programs and pursued *ad hoc* efforts to attract non-resident research companies and to assist small, entrepreneurial firms. Significant public funds were invested this way.

Private companies after 1985 invested significantly in developing new proprietary technologies. Successive breakthroughs in gene-manipulating technologies by US universities opened the opportunity for private investment in the breeding system. Calgene's patent on the agrobacterium transformation technology for *brassica* intensified investment and research by private companies into canola. Since then, private companies have patented a series of canola-related technologies, including other transformation systems, selectable markers, growth promoters, hybrid systems and oil processing technologies.

Moving downstream of the technology, agricultural chemical companies and private seed companies began the search for rDNA strands that could be introduced into plants to create novel attributes, such as herbicide tolerance, fungal or stress resistance, seed pod strength, or special oil, protein or enzyme profiles. Given the patentability of genes and the availability of production contracts and 'technology use agreements,' these investments presented good prospects for value capture.

Some private breeders have additionally focused on developing hybrid systems for canola in order to biologically capture returns. With hybrids, producers must buy new seed every year if they want the desirable hybrid trait year after year because hybrid varieties exhibit desirable characteristics in the F1 generation only; subsequent generations are a potpourri of, often undesirable, traits. Hybrid varieties therefore naturally achieve the same transaction outcome as production contracts and 'technology use agreements'. So far hybrid varieties have not been as easy to produce and have not yielded as well or as consistently as open or self pollinated varieties, which has reduced their overall competitiveness at the grower level.

The combination of new proprietary technologies, patented genes and hybrid technologies greatly increased private interest and investment in canola. Many of the seeds developed during the 1990s had attributes that created the potential for hold-up. Herbicide tolerant canolas required the use of a specific herbicide in order to be useful while canolas with particular oil characteristics needed specialized processing and marketing chains in order to be viable. The most dramatic change in the private sector was the introduction of large agrochemical companies into the plant genetics industry. AgrEvo, Dow, Monsanto and Zeneca, for example, have entered canola breeding on a significant scale. The very large capital base and international network of these companies has introduced a whole new level of capacity in canola genetics. These multinationals have vertically integrated much of the plant breeding and herbicide production intra-company in an effort to address the potential hold-up problem and to capture the economic value of these new technologies. Those firms which did not vertically integrate made credible *ex ante* investments to get asset specific research and development (e.g. Proctor & Gamble invested in Calgene to develop laurate canola and AgrEvo paid AAFC to develop Liberty-linked canola). In addition to the vertically-integrated production of genetics, herbicides and seeds, these companies rely on contracts with producers to maintain control over their property once it enters the market and have privatized the much of the extension effort as an adjunct to marketing. The most important contract used to maintain this supply chain is the production contract with producers. A production contract usually specifies that the farmer is to use registered

seed and herbicides bought from designated dealers, pay a technology use fee (for one company) and, for some, deliver all production derived from that seed either to a licensed elevator or end user. Most production contracts also include an Act-Of-God clause, which relinquishes producers of contractual obligations in the case of crop failures. In 1998, an estimated 50% of the canola acreage was planted to herbicide tolerant varieties and about half of that acreage was managed under partial production contracts. For much of the rest of the production, restricted access to herbicides provided an equivalent level of protection to the companies. These contracts ensure the owners of intellectual property that the natural propensity to practice moral hazard, with respect to holding back the final product for future seed use, is minimized. The risk is not, however, eliminated.

Despite growth in the use of property rights and contracts to protect the owner of the genetic material, there is significant potential for breeders to lose control of genetic material once it sold to producers. A single pound of canola seed can produce approximately 300 pounds of seed a year later and 90,000 pounds in two years. If a high price has to be paid for new registered genetic material this creates a very strong incentive for producers to retain some of the product for their own seed in the subsequent year or to sell some of this product to their neighbors in what is referred to as the "brown bag" market. The small volume required to cheat makes this black market impossible to eliminate. This is not a problem for those herbicide tolerant varieties that require the annual purchase of a specialized, patented chemical (e.g. Liberty, Pursuit), because the price of the herbicide rather than the price of the seed is used to capture the rents for the breeders. It is also not a problem for designer oil canolas because the product must be sold to a particular processor in order to have value. The real problem of unenforceable property rights is in the case of herbicide tolerant varieties that use generic herbicides (e.g. Roundup, which is off the patent in Canada), and in the case of open-pollinated canola varieties with improved agronomic properties. In these cases the breeders must capture much of their rents in the first year or two of release, rather than over the life of the product. Incidentally, the brown bag market creates a huge potential problem for segregation of non-transgenic varieties. Producers who have grown brown bag trans-genic seed are not going to declare it upon sale, given that they may face prosecution if they do so.

The diversity of the technologies makes industry-wide institutional solutions increasingly difficult. The development of hybrid varieties, for example, has allowed some private firms a greater ability to capture value for their genetic material. These hybrid technologies, which make second generation seed less viable, effectively eliminate the incentive for producers to retain production for future seed use. The first hybrid variety was introduced in 1989. By 1997, hybrid and synthetic varieties commanded more than a 20% market share. Although often protected with Plant Breeders Rights and production contracts, these varieties do not require the enforcement of contracts to maintain control over the use of the genetics. Because hybrid varieties produce a very poor second generation with very mixed genetic properties, there is no ability for grower to retain its agronomic benefits.

Most of these companies also use patents and plant breeders' rights to enforce their rights. Monsanto has an in-house investigations effort directed to maintaining and protecting its rights while Svalof Weibuls, one of the earliest private seed breeders, developed a plant breeders protection program that now has been spun off as the Plant Protection Institute, an industry-financed and -led institution that seeks to enforce breeders rights. Enforcement has many attributes of other development factors, including high asset specificity, non-separability and low excludability. Hence, this innovative industry structure fills the bill. The Canola Council was not suitable for this function as it involved marketers and processors, who do not have a stake in the issue, and producers who generally do not want to invest to support breeders rights. So a new institution was required.

Table 3 summarizes the percentage of canola varieties on the market by type of contractual arrangement or property rights used to secure the technology. The table also displays the market share of each category. It is interesting to note that almost all of the acreage planted to canola in 1997 was subject to some form of contract or property rights.

TABLE 3 Intellectual Property Rights Mechanisms for Canola

Reference: 96 varieties registered 1990-96	% varieties	% market share in 1997 +
Plant Breeders Rights*	37%*	55%
Private contracts for HT varieties	4%	35%
Patents on genes	4%	35%
Identity preservation for novel traits	10%	3%
Hybrids/synthetics	18%	20%
Source: Canola Council of Canada webpage and authors' calculations. *Almost all breeders apply for Plant Breeders Rights (186 applications received as of March 1998 [Canadian Food Inspection Agency, May 1998]) but many do not pursue if market expectations are low. +The numbers add to more than 100% as almost all new varieties are protected by Plant Breeders Rights.		

The more complete assignment of property rights reduced the extent of market failure at the research level and led to much more extensive private efforts for extension and market development, all of which forced a retrenchment of both the public and participatory sectors in recent years. The privatization of much of the canola research could have sidelined the Canola Council. Research, which was clearly the first and dominant priority of the Council in earlier periods, became less of an imperative. The Board of the Council was previously very receptive to new ideas and proposals from researchers, so much so that any budget constraints were passed along to marketing and administration, rather than research. This is no longer the case. The large increase in private investment in research and the refocusing of public research towards partnerships with private firms has changed the role of Council research. In 1994, the export and crusher levy was reduced to $0.30 per tonne from $0.50 per tonne (the rate since the levy

began). Some of this was made up by the introduction of voluntary producer check-offs—the Western Grains Research Foundation and the provincial development commissions in the three prairie provinces and Ontario combined have invested more than $15 million since 1983 in canola development, about half of it directed to research—which in 1998 contributed about 15% of the Council budget. In total, the Council research effort represented only about 2% of the global research effort in recent years.

One research problem that these new institutions, markets or contracts have not resolved is the difficulty of coordinating research to develop new germplasm or application of new technologies. The Council filled part of that role, as producers pooled funds with governments and the private sector (which contributed about 11% of the Council budget in 1998) to conduct pre-commercial and non-competitive research through the Council program. With the increasing complexity of the technologies and tools, the Council program was not enough. The public sector through Agriculture and Agri-food Canada and the National Research Council Plant Biotechnology Institute have also acted as coordinators. By providing platform technologies and collaborative research opportunities, the public labs have become a focal point for both discovery research into canola specific technologies and the base for acquiring germplasm, plant breeding transfer technologies and the general know-how that makes a successful research program.

As a result of these shifts in the private, participation, and public sectors, the visible output of these sectors changed dramatically. Although the public sector continued to contribute almost 40% of the research investment (not including infrastructure and various tax credits, subsidies and investment programs), its share of the proprietary output, both in terms of technologies and new varieties, dropped to below 20%. The private sector, supported with public funds, gained ownership of the majority of the new technologies and varieties.

Even as the role for associations in research came under increasing scrutiny, the provincial growers associations intensified their extension efforts to increase the rate of adoption of the new crop and to steadily improve the quality of the product. In Saskatchewan, for example, the provincial Canola Growers Association began the "Grow with Canola" program, which provided to farmers an extensive set of agronomic services, including basic variety, agronomic and fertility information. Demonstration test plots were planted, maintained and harvested with standard farm equipment as examples for the general farming population. Many participants in the sector credit these programs with the rapid expansion of canola on the Prairies. Without such a rapid take-up, the export market growth would not have been possible. The Canola Council took over that program in the 1990s but found that by then much of the extension work had been privatized and was an adjunct to private marketing programs.

The Canola Council found a new role in managing the market introduction and ensuring market access for new transgenic varieties of canola. In 1994, when AgrEvo and Monsanto received approval to commercialize transgenic varieties, neither the EU nor Japan had approved them for importation. When the government refused to use

contract registration for these new varieties, the Council stepped in and coordinated efforts to undertake a voluntary, industry-managed, identify-preserved-production system to assure both Japan and the EU that canola entering their markets would be free of the new varieties. The Council also worked with Canadian regulators and firms to develop the materials needed to get regulatory approval in those markets. The voluntary IPP system ended in 1996 when Japan approved the new varieties for import. Without the Council's effort as coordinator and honest broker, all exports of canola to Japan and the EU could have been interrupted as early as 1994.

In conclusion, there has been a dramatic increase in private funding of canola research since 1985. Several forces moved the industry in this direction. Clearly the canola industry had become an established industry with a significant production base. More effective private property rights and the increase in contracting allowed private firms to capture a greater value for their product. Hybrid varieties further enhanced the potential to capture value. Companies adopted either vertical integration to overcome the potential hold-up problem—vertical integration was led by large multinational agro-chemical companies consolidating breeding with the genetics and chemical businesses—or credible *ex ante* commitments to other breeding programs. Governments supported this move with matching grants and assistance for private research. Each of these factors contributed to the growth of the private investment in the industry, which has had a profound impact on the Canola Council and the producer commissions. They were forced to restructure their finances in order to capture some of the matching funding for producer interests. Although the research effort through the Council decreased only modestly in absolute terms over this period, the effort dropped sharply in relative terms. There was an unambiguous shift in emphasis from a coordinated focus on overall industry growth to private research focused on supply chain ends. Essentially, coordination became more difficult through the Council as information and knowledge became proprietary and confidential. As a result, a new institution in the form of public-private collaborations has evolved and the participatory sector assumed new roles in the enforcement of property rights, the co-ordination of basic research and the management of market introduction of new varieties.

Summary and Conclusions

The canola industry is the best recent example of an industry developed through an extensive research program. The complete absence of an end-product market meant that quantifying a justifiable return to private investment was impossible, which kept private firms from committing resources to do basic research and development. Viewing the significant investment risk facing the private industry as a natural barrier to entry, it was natural for the early stages of canola research and development to be predominately publicly funded. When it became clear that the industry had potential in Western Canada, private investments were forthcoming in the Rapeseed Association of Canada, a participatory industry association that was initially formed to provide greater voice into the research activities and evolved to manage the extension and market development efforts that created the base for a sustainable industry.

As canola matured as a commodity, property rights assigned and proprietary biotechnologies and hybrids developed, there was an increased opportunity for private firms to capture value from their investments by making their products excludable. After 1985 there was a dramatic increase in the private expenditures in canola research. The market failure in the commercial research area was overcome but new market failures and hold-ups emerged in the pre-commercial, non-competitive research areas (due to a lack of coordination) and in market development and commercialization. Refocused and new institutions were required to handle those failures.

This study of the canola industry has broader implications for the choice of institutions to govern research and industry development in other sectors. Biotechnology is being applied across a wide variety of products in a large number of countries. Although private capital is the driving force behind this revolution, both the public sector and producers have significant capital involved in research and, at times, may be the only institutions that may be able to overcome market failures. In sectors such as corn, cotton and soybeans, private research effort dominated product research long before the advent of biotechnologies and there are few market failures that industry cannot overcome. There may be some role for participatory or public institutions to co-ordinate pre-commercial and non-competitive research efforts. In cereals, oilseeds and many tropical products, however, there have not been effective hybrids or property rights and there is little tradition of private research and industry development. In those cases, either the public or participatory sectors may be the only institutions able to co-ordinate the necessary research and then to facilitate the farmer extension and market development to bring new biotechnology-based products to market. One solution will not fit all situations. At various stages of development different types of market failures arise, requiring new institutions to address these failures. It is important to note that the roles of the government, industry associations, and the private sector change significantly at the various stages. In the context of the canola story, the private sector now is dominant, but it is unlikely that the industry would have developed without sustained participation by the government or without the industry associations playing a coordinating role. The challenge is to transfer this successful experience to foster the development of other new crops.

Endnotes

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[2]Klein and Crawford (1978) defined the quasi-rent as "value of the asset is the excess of its value over its salvage value, that is, its value in its next best use to another renter."

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