13. Intellectual property rights and the role of public and levy-funded research: Some lessons from international experience

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The introduction of intellectual property rights (IPRs) to protect knowledge created from agricultural research, development and extension (RD&E) has, in many instances, created strong incentive for private investment and has helped to address the chronic underfunding of agricultural RD&E. However, the privatisation of RD&E is not without its challenges given the non-rival nature of knowledge. Economic theory suggests that when protected by IPRs, knowledge becomes a toll good and creates the economic conditions for a natural monopoly. In an unregulated market, toll-good industries face the dilemma of market power in the case of monopoly, or the costly fragmentation of research effort when more than one firm exists. While this dilemma can be managed through other policies, efficient outcomes are difficult to achieve in the market place, as evidenced by the outcomes in the canola and corn hybrid seed industry. Models of levy-based, industry-controlled RD&E show some promise to address these toll-good issues. The Saskatchewan Pulse Growers invests research levies on behalf of growers and manages the intellectual property (IP) produced. The Grains Research and Development Corporation (GRDC) is a shareholder along with public and private firms in three wheat-breeding firms in Australia. France has a negotiated end point royalty system. More research is needed to understand the long run impact of these alternative institutional relationships.

Introduction

The need to have well performing agricultural knowledge systems is nearly self-evident. Productivity improvements allow more to be produced from a given set of inputs. Well-performing Agricultural Knowledge Systems (AKSs) foster productivity improvement by generating knowledge and developing technologies that are put into use by the agricultural sector. They not only increase profitability and economic surplus, but also contribute to the ability of the sector to address food security and environmental goals. While some important innovations have been generated by the private sector, the policies of the public sector have been critical in shaping AKSs.

Most OECD countries have a long history of public sector dominance in crop research. In North America, publicly funded crop research was seen as a key economic development tool for more than a century. Early policy makers recognised that the ability of farmers to save seed and mimic their neighbours made it impossible for firms to capture the value from many Research, Development and Extension (RD&E) activities. Recognising the lack of private incentives, governments created large publicly funded RD&E programmes. The long and extensive record of high returns to public research (Alston *et al.*, 2000; Alston *et al.*, 2010) demonstrates the benefits from public expenditure on research, while at the same time, revealing the persistent underfunding. This latter outcome emphasizes that agricultural research faces stiff competition from other government spending priorities.

The private sector has played a very important role in agricultural RD&E when Intellectual Property Rights (IPRs) have allowed firms to capture a return from their investments. Agricultural machinery and pesticides are good examples where this has occurred. Notably, the private sector has also played a large role in crop breeding where hybrid technologies, patented traits, or vegetative reproduction allow crop breeders to capture value from their innovations.

The issue

The questions posed here are: “What are the roles for private and public sector in education, Research and Development (R&D) and extension? What defines the boundaries: market failures, public goods? How to strengthen complementarities between private and public sector?

A standard policy approach addresses the question: “Are more effective IPRs the solution to research underfunding?” On the face of it, the underfunding of agricultural research has a simple solution: create stronger and more complete IPRs where possible, subsidize private RD&E where property rights are somewhat incomplete, and continue to do public RD&E where IPRs cannot feasibly stimulate enough private investment. Unfortunately, the policy problem of underfunded research is more complex, and cannot be solved by simply addressing incomplete property rights.

This chapter highlights an aspect of private research goods that helps to refine the discussion of private and public roles in AKS. The non-rival nature of knowledge makes protected RD&E a toll good. A toll good is a good that is non-rival but, unlike pure public goods, price excludable. The cost of producing the toll good is a fixed cost that does not vary with use while the variable cost is zero, resulting in a cost structure with declining average cost and average cost greater than marginal cost. This creates the industry cost structure conditions for a natural monopoly (Lesser, 1998). This cost structure in the private crop research industry results in one of two less-than-optimal outcomes: either 1) a concentrated private research industry with distortive market power, or 2) a less concentrated industry with more competitive forces but with more-costly fragmented research.

The existence of toll goods has implications for the roles of the private and public sector in RD&E. As in other toll-good industries, such as railways, ports, and electrical power, a wide variety of public/private structures have evolved in AKSs. In agricultural research, downstream private industry organisations funded by commodity levies can play an effective role in AKSs, by creating a better alignment of incentives and a voice for the downstream users.

The remainder of the paper is organised in sections. The first section employs well-established economic concepts to describe the relationship between knowledge spillovers and private knowledge creation, while introducing the role of industry voice in the provision of public goods. The subsequent section draws on the literature to frame protected knowledge as a toll good and discusses the implications non-rival inputs have for private industry efficiency and the role public policy. This section concludes with a discussion of the North American experience in well protected crop research sectors. The third section examines the role of industry-controlled, levy-funded research as a mechanism to fund crop research and drawing from the experience of the Saskatchewan Pulse Growers and the Australian Grains Research and Development Corporation. The final section briefly summarizes the chapter.

Spillovers, knowledge and market failure

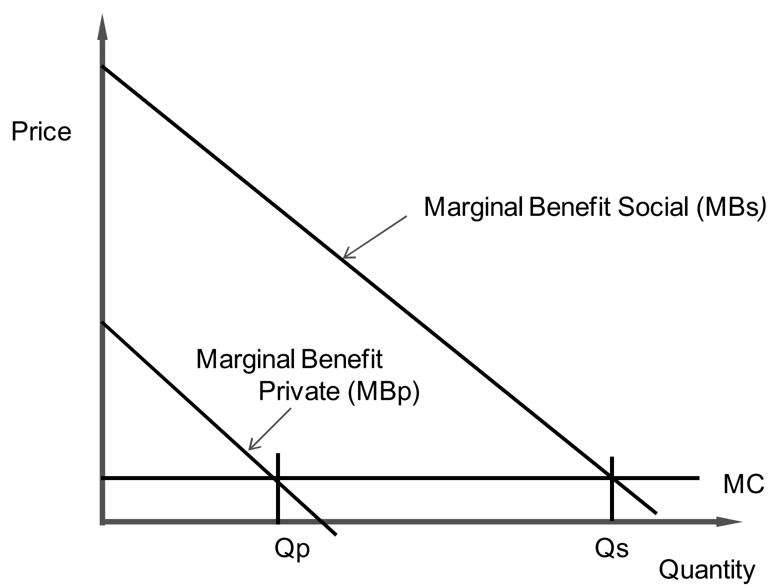
Knowledge spillovers

The simplest economic classification of private versus public goods hinges on whether a good is excludable or not. The right to exclude others from using a good is central to the notion of private property. Without the ability to exclude others, goods are essentially in the public domain and private individuals have no incentive to provide the good. If the ability to use a good "spills over" to others, and they are not obliged to pay for the good, the market demand will not reflect the good's full social value. The market demand will reflect only the flow of benefits that can be excluded if payment is not made. Economists use the term «spillovers» to refer to the benefits that are received but not paid for by the recipients in a market transaction.

Spillovers create a market failure because of the misalignment between the social marginal value of a good and the marginal cost of producing the good (Alston, 2002a). This effect is illustrated in Figure 13.1. The social marginal benefit curve represents the social value of each unit of the good provided. The private marginal benefit curve represents the market demand for the good. The spillover of benefits is represented by the vertical distance between social and private marginal benefit curves. These spillovers can be very widespread or "public" in nature (such as a reduction in greenhouse gas emissions), specific to the industry in question (such as a new agronomic practice freely adopted by producers), or specific to the individual firm (such as the benefit from replanting saved seed). Private individuals or the market will supply RD&E only to the point (*Qp*), where the private willingness to pay (*MBp*) is equal to the marginal cost (*MC*) of providing an additional unit, represented by *MC* in Figure 13.1. In this case, the market fails to provide the socially optimal amount of RD&E, (*Qs*) because at the point, *Qp* the social marginal benefit exceeds the marginal cost of producing another unit.

This market failure is commonly addressed in one of four ways: 1) the government can provide RD&E equal to *Qs*; 2) the government can create a non-market institution to provide RD&E equal to *Qs* (or the shortfall between *Qp* and *Qs*); 3) the government can provide a subsidy to private firms equal to the per unit value of the spillover; or 4) the government can correct the market failure by creating complete IPRs that allows the private firm conducting the RD&E to exclude others from using the resulting innovations. In this simple description, the IPRs would convert the innovation from a good that has to be provided by the public sector to a private good.

Figure 13.1. The private provision of goods in the presence of spillovers



Spillovers and voice

When spillovers exist and it is not feasible to create IPRs, the nature of the group that receives the non-market benefits is important for policy makers. Illustrating this point, Ronald Coase (1974) took issue with Samuelson's premise that government should pay for the provision of lighthouses because they create "public" benefits. Coase used the example of Trinity House, which was a non-profit organisation run by ship owners that had existed in the United Kingdom since 1594, to argue that it was more efficient to create a non-profit organisation that could levy a tax on ship owners to fund lighthouses because ship owners had both incentives and the knowledge to balance the cost of provision against the benefits created. In crop research, Alston, Freebairn and James (2004) argued that crop research levies are an effective crop research financing system because the burden of levy is shared by consumers and producers in roughly same proportion as the benefits that accrue from the research. Given this relationship, under a range of conditions, a producer-controlled levy-funded research organisation has the economic incentive to undertake the socially optimal amount of research.[2] Taking Coase's point, industry organisations are often very effective in AKS because they also have a superior understanding of their research requirements. Consequently, it is appropriate to give them voice in the total amount of investment and the allocation among projects and programmes.[3] More subtle questions concern how much voice ought to be given to other groups in society, and which groups.

At one end of the spectrum is a board comprised entirely of producer representatives. Under some circumstances, such a board operating to maximise benefits to its producer constituents will maximise benefits to the broader community. But industry organisations will appropriately focus on the benefits to their members, and may undervalue investments for which the benefits entail substantial spillovers that are very broad or public in nature. Likewise, producers may not be well-informed about scientific possibilities, and producer-dominated boards may not well appreciate or give appropriate priority to the interests of downstream processors and consumers in product attributes and the like. In view of these considerations, it is likely to be appropriate to include a range of representation on boards administering levy-based funds, including scientific and other specialists and representatives of processors and consumers; and in some instances it might make sense to have government or some other broader body undertake the taxation and investment decisions.

Knowledge as a toll good

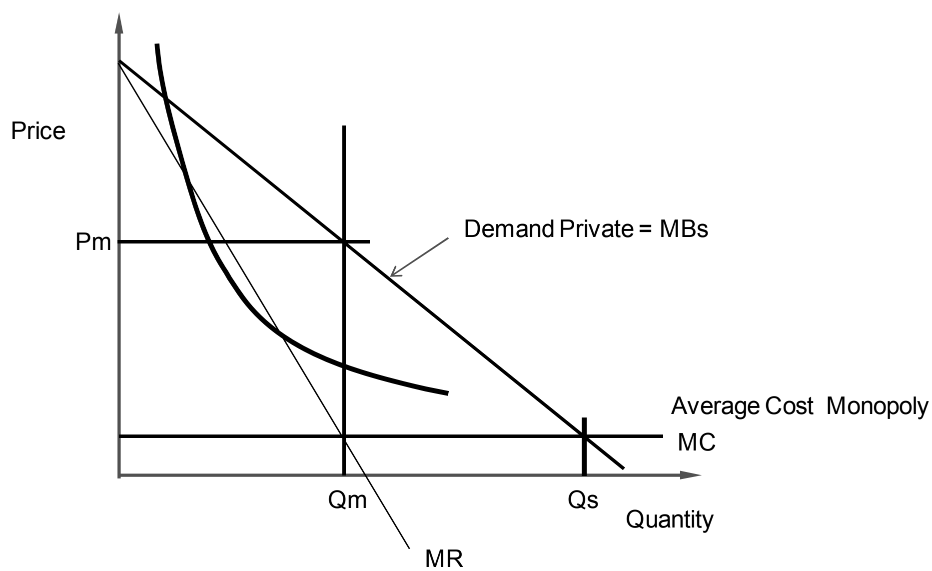
Excludability and non-rivalry

The economic literature also draws another important distinction between good types (e.g. Romer, 1994). In addition to excludability, goods differ in the extent to which use of them is rivalrous (often referred to as subtractability). Most economics goods are "rival," such that if they are used by one individual they cannot be used or consumed by another. For example, a sandwich is only eaten once, or a litre of gasoline is burned only once. However, some goods, including knowledge, are non-rival and are not diminished by use. Once created, these non-rival goods can be used any number of times and shared without incurring a marginal cost. In many cases knowledge is a classic public good in the sense that it is both non-rival, and non-excludable. Such goods will not be produced privately and, if produced by the government, must be provided for free to users.

Knowledge, when protected by IPRs, becomes a toll good (Lesser, 1998; Fulton, 1997). The non-rival nature of toll goods means that they are likely to result in significant market concentration if they are used as key inputs into a production process (e.g. new varieties protected by IPRs, used as inputs in production of seed). Because the toll-good input is non-rival, it only has to be purchased or created once. This fixed cost is incurred only once for each such good — for example, a new variety of soybeans — and the same genetic material can be used again and again without reducing its availability to others and at no additional cost. This means that the average cost of producing the final output (i.e. seed using this genetic material) decreases with the quantity produced because the cost associated with purchasing, or creating, the non-rival input (the new variety) is spread over more units of output. The declining average cost implies that large firms will always have a cost advantage over smaller firms. The lowest industry average cost can be achieved if the good is supplied by a single monopoly. Figure 13.2 shows the cost structure for the production of a product that is produced using a toll good. Toll-good industries for which fixed costs represent a large share of total costs, such as railways, software companies, or electrical distribution networks, are often referred to as natural monopolies.

The toll-good nature of intellectual property (IP) has profound implications for the cost structure of the research industry. Consider the case of breeding new wheat varieties. If one begins with a hypothetical situation where all research is organised in the most cost-effective manner and all the global knowledge generated is shared without transaction cost, this would be the lower bound for the industry average cost curve, where the research costs are minimised. This average cost curve would be downward sloping as the fixed costs of the research that generated the particular innovation are spread over more and more units of output that use that innovation.

Figure 13.2. The cost structure toll-good monopolist



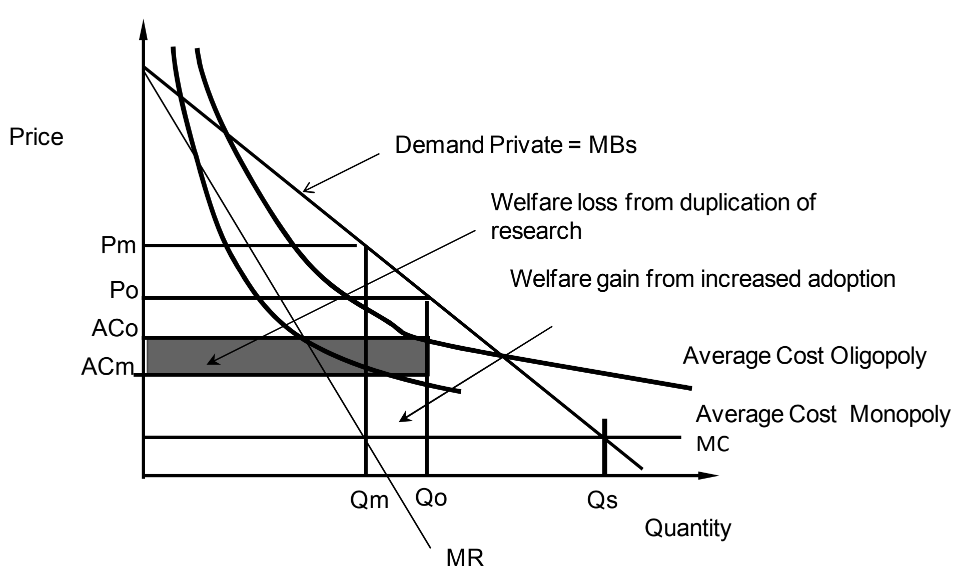
Market power versus research fragmentation

Here is the dilemma. If the wheat breeding industry were made up of one firm, the firm would have the incentive to minimize costs and would operate on this industry minimum average cost curve. However, when a firm is selling to the whole market, the demand for the a new technology, trait, or variety will be price sensitive, (downward sloping) and the single firm will have an incentive behave as a monopolist and maximise its profits by setting the price of the new variety such that the marginal revenue is equal to the marginal cost (Moschini and Lapan, 1997). For example, Monsanto, which has a monopoly on its Roundup Ready™ technology, will not earn rents if the price is set so high that farmers will not adopt the technology or so low that that Monsanto has no margin. The management is paid to find the price where the return to share holders is maximised and this will always be at point where price is greater than the firm's marginal cost. This "monopoly" pricing behaviour reduces economic surplus by deterring adoption. Economic benefits to society are forgone because the price precludes some farmers from adopting, who could benefit and would be willing to pay more for the technology than the zero marginal cost of licensing another acre but are precluded because of the price charged. For example, if Monsanto charges USD 15 per acre for the use of its Roundup Ready™ technology, all farmers who are willing to pay less than USD 15 acre do not adopt the technology even though no resources would be required by

Monsanto on the margin to provide this benefit. As drawn in Figure 13.2, the variety would be sold at price *Pm*, which would create a deadweight loss by inhibiting adoption, compared with a scenario where the technology was free (i.e. the price is zero) or Monsanto could price discriminate perfectly, and charge each farmer his willingness to pay for the technology. In sum, a single firm will operate on the lowest industry marginal cost curve monopoly but will create economic inefficiency by charging a price that is socially too high, (greater than marginal cost), which deters adoption, unless it can act as a perfectly discriminating monopolist.

Competition reduces price but creates another issue. If the industry is profitable it will attract entry by other firms. Typically, research-intensive industries have more than one R&D firm. If two firms were engaged in any form of price competition, this would decrease the price charged for seed and reduce the efficiency loss associated with the over-pricing of the research output. However, this increased competition also comes at a cost. If two identical firms were engaged in research, and each produced effectively identical varieties that were sold to one half of the market, each would incur the fixed cost of research. This duplication of effort would double the research cost, which would shift the industry average cost upward, imposing a loss on society. The net effect on social welfare is difficult to assess. On one hand competition reduces seed prices toward marginal cost, encouraging adoption, on the other hand the duplication of effort increases the cost of the research. This effect is illustrated in Figure 13.3. The entry of additional firms reduces the oligopoly price *Po* below the monopoly price, *Pm*, which encourages more adoption. However, firm entry also increases the average cost of research for a given research outcome, from *ACm* to *ACo* because of the duplication of research effort. While the optimal amount of entry is difficult to assess, the toll-good nature of the research makes this dilemma nearly impossible to avoid in an unregulated private market. As shown in Figure 13.3, the net effect of firm entry will be the gain in surplus from additional adoption minus the additional research costs associated with the duplication of effort.

Figure 13.3. The welfare impact of entry in a toll-good industry



Experience in agricultural biotech crop research industry in North America

In North America, the Plant Variety Protection Act, utility patents and hybrid technologies have allowed strong IP protection, and created powerful economic incentives for private investment in several field crops, most notably in corn, soybeans, canola and cotton. As theory would predict, the toll-good industry is dominated by a small number of firms, each with research programmes large enough to capture some of the economies of scale (Howard, 2009). The impact on research investment in these crops has been substantial. As reported by Wilson and Dahl (2010), the five largest firms have made substantial and growing investments over the past decade, and invest a sum of approximately USD 2 billion per year in crop genetic improvement.

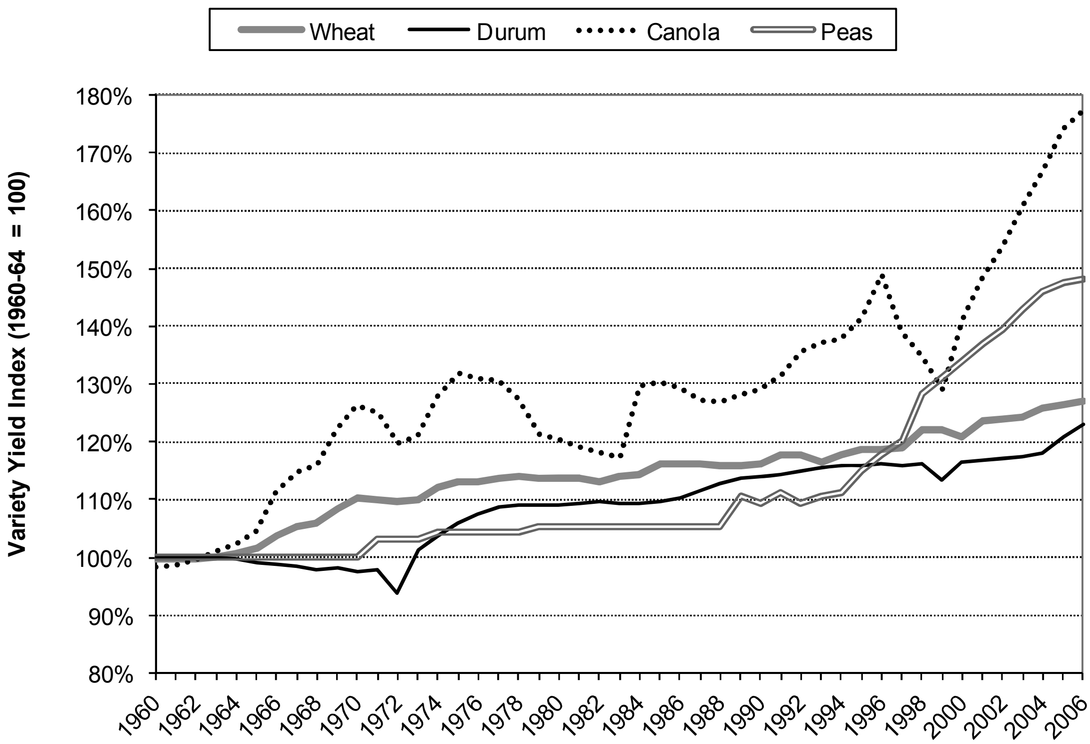
The impact of significant private investment is apparent in a number of ways. First of all, for the large crops in the United States, where IP can be protected by utility patents or hybrid technologies, producers have made the decision to adopt privately-owned varieties. The adoption of private varieties is virtually 100% for corn and well over 90% for soybeans and cotton. Transgenic herbicide tolerance has been especially important for soybeans, allowing the crop area to expand considerably. In corn insect resistance, herbicide tolerance, and other genetics have allowed yield to continue to increase. In cotton, insect resistance has reduced pesticide use. Generally, the gains from the research include increased farm productivity, greater crop production, reduced pesticide use, consumer benefits though lower prices, and a return to share holders (Zilberman *et al.*, 2010; National Research Council, 2010).

In Canada, canola has become the second-largest crop after wheat and is a remarkable success story. Public research and breeding that began in the 1960's created double low rapeseed in Canada, genetics that were trademarked as "Canola". During this embryonic period, the Rapeseed Association of Canada was an important catalyst for industry development (Gray *et al.*, 2001). In the 1980's, with the development of patentable transgenic processes the private sector began to make significant investments in canola genetics. Soon afterward Agriculture and Agri-Food Canada made a decision to withdraw from the commercial seed development and move its research upstream to support the private seed industry. Privately-produced, herbicide-tolerant varieties were introduced in the mid 1990s and reached nearly complete adoption by 2005. In the latter part of this adoption period, hybrid varieties were introduced and now dominate seed sales. This innovative industry recently developed and commercialised high oleic Canola creating a fatty acid profile that reduces trans-fatty acid development during frying. Grown on over a million acres, in value and volume terms, high oleic may be the largest engineered functional food in the world.

Private research has been substantial during the past decade but little information is available publicly about private expenditures levels. A 2007 survey of the industry by the Canadian Seed Trade Association (CSTA, 2008), estimated a total investment of CAD 56 million in private plant breeding investment in 2007. Of the total of CAD 102 million per year of planned investment in 2012, 75% was for canola research (CSTA, 2008). Although, the public institutions no longer produce commercial varieties, public institutions continue to invest up to CAD 20 million per year in pre-breeding research and germplasm development.

Yield potential of canola has grown much faster for canola, for which R&D is primarily privately funded, than wheat, for which R&D is primarily publically funded in Canada. As shown in Figure 13.4, the yield index for adopted canola varieties has grown 75% since 1960 and has shown strong growth in the past decade. In contrast, the yield index for wheat and durum varieties have only increased by roughly 25% during the same period. As a result, canola has increasingly become the crop of choice for many producers, with the expanding seeded area being constrained only by climate suitability and crop rotations for the management of fungal diseases.

Figure 13.4. Adoption weighted variety yield index by crop, Western Canada, 1960-2006



Source: Veeman and Gray (2010, Figure 6.5, p. 132).

The benefits from private investments in canola have been widespread. Producers enjoy higher yields, lower herbicide costs and more flexibility in the timing of herbicide application. The canola processing industry has also expanded and the seed companies enjoy strong seeds sales with high seed prices. Positive human health benefits may have accrued to consumers from lower saturated fats and the higher oleic acid profiles.

Despite the widespread adoption of privately developed varieties, and the apparent gains from the additional research investment, the developments in the North American seed industry have not been without controversy. Issues of market power, seed pricing and knowledge sharing have both come under some scrutiny from economists and regulatory bodies (Stiegert *et al.*, 2010; Wright and Pardey, 2006; Wilson and Dahl, 2010).

The protection of IP afforded by hybrid technologies and patents has had a significant impact on the development of a private seed industry for several important crops. As shown in Table 13.1 the pattern of seed sales and research expenditure for US corn, US soybeans and Canadian Canola, have some striking similarities. Each industry seed sales represent roughly 10% of gross crop income, seed production costs are a small fraction of the seed prices, and each seed industry invests about 10% its gross sales into research (i.e. about 1% of gross crop income).

The approximate rate of 1% of gross farm sales invested in variety development by the private firms for corn, soybeans, and canola is significant. This investment rate is two to three times the total public and private investment rate for wheat breeding in Canada. Thus, IPRs are a policy tool that can be used to address the underfunding issue as identified at the outset of this paper. This funding mechanism may represent a significant improvement over an underfunded public research system, especially considering the scale economies enjoyed by these large multi-national private firms.

Table 13.1. Estimated revenue, rents and research expenditures for IP protected crops, 2010

2010 estimates		US corn	US soybeans	Canadian canola
Farm seed costs per acre	USD	75[a]	52[a]	46[b]
Area sown	Million acres	88[c]	79[c]	17[d]
Total seed expenditure	USD Million	6 593	4 100	773
Gross value of crop at farm	USD Million	66 700[e]	38 280[e]	5 074[f]
Seed cost/ farm gross income	**%**	**10**	**11**	**15**
Seed production costs	USD/bushel	24.0[g]	13.5[h]	56.0[g]
Seed rate	Bushel/acre	0.25[i]	1.20[j]	0.10[k]
Seed production costs	USD/seeded acre	6.0	16.2	5.6
Total seed production costs	USD Million	527	1 280	94
Gross seed margin	USD Million	6 065[l]	2 820[l]	578[l]
Total private research expenditures on all crop improvement research	USD Million	2 000[m]	2 000[m]	87[n]
Specific crop % of total private	%	34[o]	17[p]	75[q]
Estimated crop-specific research expenditures	USD Million	680	340	65
Private research/farm gross	**%**	**1.0**	**0.9**	**1.3**
Private investment/gross seed margin	**%**	**11.2**	**12.7**	**9.6**

a. NASS, USDA Farm Prices Paid 2011, USDA.
b. Author's estimate based on USD 8 per pound paid in 2010 plus a USD 15 Technical Use Agreement fee for Roundup Ready™ Canola on 40% of area.
c. USDA final seeded acre estimate.
d. Statistics Canada 22-007 final estimate.
e. NASS, USDA Crop Values Annual Survey.
f. Statistics Canada 001-0010.
g. Hybrid seed production cost estimated as four times the cost of non-hybrid commercial price of USD 6/bushel.
h. Estimated as 1.5 times the cost of commercial production.
i. Thirty thousand seeds per acre at 2 000 seeds/pound.
j. Seventy-two pounds per acre.
k. Five pounds per acre.
l. Gross value on seed purchases – seed production costs.
m. Wilson and Dahl (2010).
n. Private research expenditure estimate 2007, Canadian Seed Trade Association.
o. Based on corn's share research in 1996 reported in Fernandez-Cornejo (2004).
p. Corn research estimate x soybeans/corn sales.
q. Author's estimate.

A striking feature of these profiles is the 10% share of farm gross income revenue going to seed purchases. This large share of gross income is similar in size to the factor share for land rental. This indicates that producers benefit a great deal from these new varieties and are willing to pay for them, and that with IPRs the seed firms are able to capture a significant portion of the benefits from varietal improvement. It also suggests that these seed prices are high enough to materially affect adoption decisions and that at lower seed prices the adoption of these crops would be even more widespread.[4]

The fact that these seed prices are well above the marginal cost of seed production is consistent with the toll-good nature of the industry (Moschini and Lapan, 1997). The economic significance of seed cost has attracted the attention of economists. Several recent studies by Stiegert, Shi, and Chavas (Stiegert *et al.*, 2010) have found that the pricing of traits is correlated with measures of market concentration. Wilson and Dahl (2010) and Fernandez-Cornejo and Caswell (2006) argue that, on balance, the economies of size realised by concentration more than offset the higher pricing incentives. As recently as 2007 the Anti-Trust Division of the US Department of Justice held an inquiry into Monsanto's pricing behaviour (Wilson and Dahl, 2010). While unresolved, this issue continues to be a concern for policy makers.

As mentioned previously, the non-rival nature of knowledge makes industry cost a function of the degree to which knowledge is shared. Concerns over knowledge sharing and exchange in the crop research industry have been documented in a growing economic literature. A firm might not license its protected IP for several reasons. The first is the management of strategic assets. When firms are in close competition, they may deliberately keep their proprietary knowledge secret rather than license it to a rival. Second, an anti-commons problem (Graff *et al.*, 2003; Heller, 1998; Wright and Pardey, 2006) can exist. If many firms own complementary IP, the *ex post* bargaining behaviour of the individual owners may make it difficult and sometimes impossible to reach an incentive-compatible sharing agreement among all of the requisite owners. The classic case of this is GoldenRice™, which was estimated to contain 40 pieces of IP in the United States that were owned by at least 12 different organisations (Kryder *et al.*, 2000). Finally, the large number of IP claims can give rise to excessive transactions costs. To illustrate the vast number of patents, on 20 March 2011 a simple search of the US patent database revealed 3 054 patents that are related to stress tolerance and wheat. Searching this large database and identifying which patents are potentially useful, determining what patents are enforceable, and what IP can be safely used without violating other patents, is a time-consuming and costly undertaking. The result, often called the «patent» thicket (Wright and Pardey, 2006), adds to the cost of protection and use of IP. For all of the above reasons, firms often have not licensed their IP and have opted to develop their own research platforms, which duplicate effort and drive up the industry cost curve.

Despite the obstacles, some private mechanisms for sharing knowledge can and do evolve. This is important because the lowest industry average cost curve can be achieved with multiple firms in the industry if they can find a way to "share" toll goods. Research consortiums, where the funding partners agree to share the knowledge generated, have been used occasionally by both public and private research institutions. Since 2005, the largely autonomous multinational biotech firms have developed numerous cross-licensing agreements amongst firms (Smyth and Gray, 2011; Galushko *et al.*, 2010; Howard, 2009). These agreements allow for genetic traits and processes owned by separate firms to be combined (or stacked) and marketed as bundles. This is a very important development because it allows the non-rival knowledge to be shared, which lowers the cost of creating superior genetics. However, these agreements can also constrain the nature of competition among firms, by establishing licensing fees, pricing protocols and bundling options.

In summary, the strong IP protection brought about by biotech-related utility patents and hybrid technologies has been successful in simulating substantial private investment, and created significant economic benefits by reducing the underfunding of crop varietal research. In doing so, this strong IPR regime created a concentrated toll-good industry, with extensive economies of size giving rise to concerns over incentive problems related to pricing, versus fragmentation or duplication of effort. As has occurred in other sectors of the economy, the emergence of a toll-good industry may have implications for economic policy, the role of the public research, and the viability of alternative institutional arrangements in AKS. The remainder of this paper will explore some of these alternatives.

Alternative institutional arrangements to manage toll goods

In general, governments have used five main approaches to managing toll goods (Fulton and Gray, 2007).

- Government produces the toll good through a subsidy.
- Government produces the toll good through a non-profit state monopoly that receives limited subsidies.
- Government grants a private firm the monopoly power to provide the good, but then regulates the rate of return (or pricing or other aspects of the firm's economic activities).
- Government allows an oligopoly to produce toll goods with some regulations to enhance entry and competition among firms.
- The government creates or facilitates the development of a non-profit organisation to produce the toll good.

Examples of most of the approaches mentioned above can be found in AKSs. Governments have often created publically funded research institutions that provide knowledge to the sector gratis. Crop breeding undertaken by government has the advantage of solving the over-pricing issue, but typically suffers from public under-funding and other efficiency issues related to market responsiveness and researcher incentives.

In an attempt to improve governance of research, governments have often also created parastatal organisations or state-supported research institutions, which use a corporate reporting structure and operated at arms length from government control. Universities and other non-profit institutions often receive public support for their research, but are given incentives to use property rights to earn revenue from their IP. However, if such institutions evolve to the point of becoming profitable, governments often sell or privatize them for fear of crowding out private investment.

The third option, to sanction a private monopoly with a regulated rate of return, is common in public utilities but very rare, or perhaps even non-existent, in AKSs. If examples do exist they would be interesting to examine.

The fourth option, of regulating an oligopoly, is more common in agricultural research. In the hybrid cotton industry, the Department of Justice required Monsanto to divest itself of a seed company and some cotton seed lines as part of a merger with Delta&Pine Land to prevent over-concentration in the industry (DOJ, 2007). IPR rules have also been designed to enhance competition. In the case of conventional breeding, most of the valuable genetics are embodied in the latest varieties. Sharing of this knowledge among competitors was achieved through a "breeders' exemption" which allowed other breeders to use others' varieties in their breeding programmes (Holman and Galushko, 2007). In effect, this allowed potential competitors to use the knowledge created by other breeders. Other than the sequential aspect, the breeder privilege is not dissimilar to the access regulations for telecom and electrical networks where governments regulated the access to these toll goods in an attempt to enhance the competitiveness of the industry without a costly duplication of effort.

The fifth option, to create a levy-funded, non-profit organisation to undertake research, is common in AKS. Many countries enable industry organisations to levy a tax on production (or collect a tax on behalf of a producer organisation) to generate revenues that can be used for research and/or market development. As mentioned previously these organisations often have the additional advantage of giving voice to the downstream users of the research. In North America, producers can organise, develop plans, and vote to create levy-based research programmes, wherein producers can manage levy-based funds for the purposes of research and development. This approach avoids the over-pricing issue and has the advantage of giving industry voice in research funding and allocation decisions. Many of these organisations however also suffer from collective underfunding because of producer heterogeneity and horizon problems and may not have the economies scale or scope of larger private research organisations.

Of the five policy options used to provide toll goods discussed above, the fifth option is perhaps the most appealing from an incentive compatibility perspective and moreover there are existing examples of success. The use of these types of organisations are used in AKS has direct implications for the role and scope of public institutions involved in research. While we can find many examples of producer levy organisations undertaking research, some are more successful than others. The Saskatchewan Pulse Growers and the Grains Research and Development Corporation in Australia stand out as examples of organisations that have been successful in investing a significant amount of levy-based funding for the benefit of the producers and others they represent.

Levy funded research

Any royalty paid to variety owners does not reflect the marginal cost of using the knowledge but instead is a contribution toward the fixed cost of the R&D used to create the IP. Any royalty charged for new IP will discourage adoption, compared with the theoretical ideal of pricing at the marginal cost or replication, zero. Second, market mechanism exists, other than costly firm entry and duplication of effort, to ensure that the royalty charged by a private industry will approximate the total cost of providing the knowledge.

Levy funded research controlled by downstream users has several advantages over the use of strong IPRs to fund research:

- Because the funding of research comes from a levy on output, royalties can be set at zero to encourage the most rapid adoption of the new technology.

- Downstream users have an incentive to consider any spillovers that they may receive from the research in their funding decisions, so they can fund RD&E even without complete IPRs. For example, growers have an incentive to fund even unprotectable agronomic research.
- The voice given to the downstream industry is important because they have the incentive to determine the appropriate amount of research because the users of research are paying for research.
- At the local industry level these organisations can encourage knowledge sharing and discourage unnecessary duplication of effort without creating pricing and incentive problems.
- As semi-private institutions these organisations may be better able than government to enter agreements with the private firms in the research industry.

The primary obstacle faced by some levy-based organisations is related to collective action and the free-rider problem. Some levy-based programmes are mandatory, with all participants obliged to contribute; others are voluntary, such as some a Canadian schemes that have allowed refunds of levies that are collected in the first instance on all of production. In a voluntary scheme, including programmes with refundable levies, research benefits can accrue as a type of spillover to producers who choose not to pay the levy and instead to free ride on their neighbours' contributions. Voluntary levies tend be maintained at very low rates to mitigate the tendency for some producers to opt out and free ride on the benefits.

Saskatchewan pulse growers

The Saskatchewan Pulse Development Board, also known as Saskatchewan Pulse Growers (SPG) provides an excellent Canadian example of how growers can become actively involved in crop breeding and drive the development of an industry. The SPG is funded through a check-off of 1% of the value of the gross sale of all pulse crops in the province of Saskatchewan. Unlike other commodities, which in Saskatchewan are all established as Commissions, the SPG's levy is mandatory (i.e. non-refundable). In 2003, after twenty years of success, growers voted for an increase in the levy rate from 0.5 to 1%. This levy rate is similar to that of the Australian GRDC and is far higher than the rates that exist for other Canadian crops. For example, the Western Grain Development Fund levy is less than 0.2% current gross revenue.

SPG currently represents over 18 000 pulse crop producers in Saskatchewan and is directed by a board of seven elected pulse farmers, who are each elected for a three-year term. The Pulse Crop Development Plan Regulations, originally written in 1984 and subsequently amended through Board Orders, outline the mandate of the organisation and its legal ability to collect the check-off. Under the Provincial Natural Products Marketing Act (the Agri-food Act), pulse buyers must register with SPG annually, collect the check-off on all purchases (like a sales tax) and make monthly payments to SPG with complete producer information. The Saskatchewan Agri-Food Council, an independent body appointed by the Minister of Agriculture and Food, supervises the activities of all organisations established under the Agri-Food Act.

The revenue base of the SPG has grown with the industry. Between 1985 and 2004, CAD 25 million was collected. With expanded acreage and higher prices, annual revenues have exceeded CAD 12 million in each of the past two years. Governments do not provide matching funds to the pulse levy but do offer research tax credits and have been active in providing research infrastructure and other support for pulse research. SPG has noted the decline of Saskatchewan government funding in recent years.

Saskatchewan Pulse Growers use the revenue from the check-off to fund research projects, extension and communications activities, the variety release programme and general operations of the organisation. It has been used for a number of activities of direct benefit to growers. These include support of the University of Saskatchewan's Crop Development Centre's (CDC) pulse breeding programme, royalty-free seed to select-status seed growers, agronomic research, Pulse Days, the Pulse Production Manual and efforts to increase demand through domestic and international market development programmes. SPG also invested with provincial and federal governments in new facilities at the CDC.

The CDC is the exclusive recipient of funding for breeding through the SPG check-off. All developed varieties are technically owned by the CDC; however, the SPG receives exclusive rights to distribution of all new CDC pulse varieties in exchange for its financial contribution. SPG in turn provides industry access to new pulse varieties through several different release programmes, each designed to maximise grower returns from their investments.

The new varieties bred for large established markets are distributed under the general release programme, which offers seed to all select-status seed growers in Saskatchewan and Alberta on a royalty-free basis. This wide distribution ensures competition in seed propagation and distribution. Under the Niche Variety Release Program, a single firm is given exclusive access to a new class of pulses for a decade, in return for royalties paid to SPG. This gives the private firm the time and incentive to develop these markets. A private firm is also given the rights to foreign distribution of new varieties (after a period of time) in return for royalties, thereby giving the firm the incentive to market and protect these varieties where it is possible to do so. The SPG grants access to BASF for certain lentil varieties so the firm can incorporate the Clearfield™ herbicide tolerant trait. To ensure fair pricing of the Clearfield varieties, SPG releases the same variety without the herbicide tolerant trait at least a year prior to the Clearfield variety. Finally, the SPG has offered financial compensation for some private firms that agree to release independently developed varieties so that they can compete with the royalty-free CDC varieties.

The SPG breeding programme has been a remarkable success. The programme has developed an industry that provides benefits for growers and the industry as whole. Gray *et al.* (2008) estimates that over its first 25 years of its existence producers have earned a 20% annual internal rate of return on their check-off investments. As shown in Figure 13.4, Saskatchewan pea variety yields increased nearly 40% in just two decades. The pulse industry has also helped to diversify the income base of growers, while extending crop rotations, improving soil organic matter, and sequestering carbon from the atmosphere.

The SPG is an example of levy-funded, producer-controlled AKS that has effectively addressed many of the market failures related to knowledge and technology spillovers and the toll-good nature of IP. While the corporate research sector is also involved in pulse research, the SPG has retained control over the germplasm and varieties it has funded. The ability of the SPG to work with governments and the corporate sector, and to have growers recently vote in support a 1% levy is a testament to its success.

The Australian AKS

The Australian AKS has undergone very significant transformation over the past 25 years, moving from a predominantly publicly funded and managed system to one where levy and royalty-based funding play primary roles in applied research, development and extension. The Grains Research and Development Corporation (GRDC) was established in 1989 under Primary Industry and Energy Research and Development Act, which established more than a dozen "Research and Development Corporations" (RDCs) each related to a different sector of the rural economy. The GRDC is funded by a mandatory non-refundable research levy of 1% on the farm sale of 25 field crops, which is matched by the Australian Government up to a maximum of 0.5%.[5]

The GRDC reports to an eight member board of directors appointed by the Commonwealth Department of Agriculture and Fisheries (GRDC, 2011); six of these members are appointed by a national producer organisation. The GRDC has three regional advisory councils and one national advisory council that provide a voice for regional research priorities. In addition to this formal regional representation, the GRDC and its panels hold regular meetings with producer organisations to gather input into research priorities (GRDC, 2011).

While the RDCs collectively play a major role in financing agricultural research in Australia, they only account for one-third of total research funding. Several federal agencies and state governments fund different aspects of agricultural research. As a large pool of resources organised at the national level, the RDCs have been successful in providing a funding and research coordinating mechanism for commodity crops.

A second very important catalyst of change in the Australian AKS was a change in plant breeders' rights (PBR) in 1994 that allowed variety owners to charge end-point royalties (EPRs) for their varieties. With an end-point royalty, any farmer who grows a PBR variety is required to pay a specified royalty to the variety owner on every ton of grain produced and sold, which allows the variety owner to capture a return, even with farm saved seed. With this development, the GRDC saw an opportunity to develop fully commercial wheat-breeding programmes and put out a tender, looking for partners to create three new wheat breeding companies. After a period of transitional support from the GRDC, each firm will eventually be funded entirely from end-point royalties. As outlined in Table 13.2, each company has a minority multinational shareholder, which has been an important source of technology for these fledgling wheat-breeding firms. Meanwhile, the GRDC, which no longer has to fund breeding activities for wheat, can divert its resources to pre-breeding research, further enhancing the stock of knowledge in the Australian AKS.

From the perspective of managing toll goods, the future developments in the fledgling commercial breeding industry will be interesting. With further adoption of existing varieties and increasing EPR rates, this breeding industry can look forward to rapidly growing royalty revenue streams in an industry where market shares will be determined by a few key varieties. It will be interesting to see how these commercial firms — with GRDC, public, and private shareholders — will price their varieties in the future. Will they set price equal to average cost or to maximise the return to shareholders? If they are profitable will they expand research or return dividends to shareholders? If dividends are paid, where will the GRDC and public shareholders reinvest these funds? Given the economies of scale and the potential volatility of revenue, will we see mergers among these firms? While the answers to these questions are still unclear, the presence of the GRDC and public institutions as significant shareholders, can reflect the interests of downstream producers and the public in future decisions as they grapple with toll-good issues.

Table 13.2. Major wheat breeding corporations in Australia 2010

Australian Grain Technologies Pty Ltd
Location and staff: Adelaide, Narrabri, Dubbo, Horsham, Roseworthy, Esperance, Perth: 48 full-time employees.
Shareholders/owners: Vilmorin & Cie (Limagrain), South Australian Research and Development Institute (SARDI), University of Adelaide, Grain Research and Development Corporation (GRDC) (39%).
Breeding programme: Five wheat breeding programmes for varieties adapted to different agronomy/growing conditions and soils including daylight length, temperature, soil type, diseases and specific regional quality needs.
HRZ Wheats Pty Ltd
Location and staff: Canberra and Lincoln (New Zealand): equivalent of five staff under contract with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and New Zealand Institute for Plant and Food Research (NZPFR).
Shareholders/owners: CSIRO, NZPFR, Landmark Operations Ltd, GRDC (40%).
Commercial partner: All HRZ varieties are marketed through Australian Wheat Board (AWB) Seeds.
Breeding Programme: International and national gene pools; spring wheats and winter wheats; hard milling wheats.
InterGrain Pty Ltd
Location and staff: Perth, Wongan Hills, Melbourne, Horsham: 30 staff.
Shareholders/owners: Western Australia State Government, GRDC (35%), Monsanto.
Commercial Partner: All InterGrain wheat varieties are marketed through Nuseed, www.seedpool.com.au.
Breeding programme: Three regional breeding programmes servicing Western Australia, South Australia, Victoria and New South Wales; a specialist programme provides support in fast tracking disease resistance and elimination of critical defects; and a research and development programme in collaboration with Monsanto to increase the use of genotypic technologies in the core breeding programmes.
Longreach Plant Breeders Pty Ltd
Location and Staff: Narrabri, Clare, Melbourne, York, Adelaide: ten staff.
Shareholders/Owners: Pacific Seeds Pty Ltd, Syngenta.
Breeding Programme: Breeding for four distinct regions, plus breeding alliance for soft wheats.

Source: Grains Research and Development Corporation, GRDC (2011).

Crop research funding in Australia has several attractive features. The introduction of the RDCs has increased the amount of agricultural research being conducted, while committing government expenditures and establishing a national coordinating mechanism. Levy-based funding can still operate where spillovers are large. The establishment of EPRs along with direct investments by the GRDC and State governments has attracted some multinational investment and technology, and established a private seed industry. The combined presence of GRDC and public shareholders as coowners of the firms changes the incentives and expected behaviour of this toll-good industry, presenting a mechanism for dealing with over-pricing and knowledge-sharing issues that would arise otherwise.

An interesting variant of the Australian and Canadian levy models occurs in France, where farmers pay a uniform levy of EUR 0.5 per tonne of bread wheat marketed. While 15% of the levy is invested in variety testing, the remainder is paid to variety owners in proportion to the tonnage of each variety sold. In effect this is a uniform end-point royalty paid to variety owners. The French levy rate, which is negotiated between the farmer organisations and the seed industry, is too low to support significant amounts of research. If able to operate with a higher levy rate, the French system could create an interesting funding model for the toll-good research industry, by being able manage research spillovers and output pricing, while creating strong incentives for innovation.

Conclusion

Research spillovers and the non-rival nature of knowledge are both sources of market failure. Policy makers have responded to research spillovers firstly with the public provision of crop research. Over time, IP rights have been developed to address some forms of knowledge spillovers, creating incentives for the private provision of crop research.

Well-established IPRs stimulate the development of a private agricultural research industry with economies of size and the cost structure of a toll-good industry. In these industries market power and the costly fragmentation of effort are both significant issues. In crops where hybrid seed and patented traits play a significant role, seed prices have risen significantly over time. Farmer now pay upwards of 10% of gross revenue to access these superior varieties, which limits adoption. Approximately 1% of gross crop revenue is invested in private breeding activities.

Given the persistent economic losses associated with spillovers, market power, and research fragmentation, both public and levy funded research organisations can play an important role in creating efficient agricultural knowledge systems. Industry-directed, levy-funded research can have an advantage over public-funded research by giving voice to downstream knowledge users.

Examples of successful levy-funded industry-directed crop research organisations include the Saskatchewan Pulse Growers and Australia's Grains Research and Development Corporation. The negotiated, uniform end-point royalty system used in the French bread wheat industry also has some interesting attributes for the management of a toll-good industry.

More research is needed to fully understand the economic implications of various institutional options. Toll-good industries will be encumbered by market power and fragmentation issues. A great deal remains to be learned about the operation of levy-based, industry-directed agricultural research funding organisations and the long-term effectiveness of their investments. These organisations have potential advantages from vertical integration, but face challenges related to the provision of collective goods. New partnerships with public and private firms need to be examined. The incentives and outcomes of various institutional structures require additional study, including the study of a variant where levies are used to provide uniform end-point royalties negotiated with downstream producers.

Notes

1. University of Saskatchewan, Canada
2. Alston (2002b) has also pointed out that heterogeneity within producer groups and the nearing retirement age of some producers may result in a systematic under investment by producer groups, which can be addressed by matching funding.
3. For a more in depth discussion of voice, see Picciotto (1995).
4. At these seed prices farmer have an incentive to restrict seeding rates to socially sub-optimal levels, creating another source of inefficiency.
5. The government matching of industry levies serves to offset a number of important incentive problems that may inhibit producer boards from setting high enough levy rates and at the same time it helps make up the difference between the national and industry interest. First, it recognizes that knowledge generated from research inevitably spills over to benefit other industries. Second, it recognizes that differences exist among producers in terms of their owned assets, abilities, ages, farm enterprises, locations, and propensity for adopting innovations arising from research investments, which mean they do not all stand to receive equal benefits from invested levy dollars. Third, it represents a credible commitment of government support, and makes it more difficult for governments to back away from funding research as industry increases its research investment.

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From:

Improving Agricultural Knowledge and Innovation Systems

OECD Conference Proceedings

Access the complete publication at:
https://doi.org/10.1787/9789264167445-en

Please cite this chapter as:

Gray, Richard (2012), "Intellectual property rights and the role of public and levy-funded research: Some lessons from international experience", in OECD, *Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264167445-16-en

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