The Privatization of British Wheat Breeding: What can Canada learn?

Viktoriya Galushko
Department of Economics, University of Regina

Richard Gray
Department of Bioresource Policy, Business and Economics,
University of Saskatchewan

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Executive Summary

Agriculture and Agri-Food Canada currently has plans to withdraw from wheat variety commercialization and shift the focus to upstream germplasm development activities. If there is going to be a transition toward privately funded wheat variety development, the important question is: “How can this be done in a way that maximizes the research potential of the wheat industry?”

The UK experience is an excellent case study for examining the consequences and implications of wheat breeding privatization. In 1987, Cambridge’s Plant Breeding Institute (PBI) was sold to Unilever marking an end to public wheat breeding in the UK. The twenty five years that have elapsed since the sale is sufficient time to be able to observe some of the longer run benefits and costs of privatization, to fully see what has worked well, and to understand what could have been done differently in the transformation from publicly funded to privately funded wheat breeding.

The information and analysis presented in this paper are largely based on personal interviews conducted by R. Gray and V. Galushko with sixteen people involved in wheat research/breeding in the UK during early July 2012. The interviews reflect viewpoints of both public researchers and private breeders including wheat scientists from the University of Bristol, John Innes Centre, Rothamsted Research, and National Institute of Agricultural Botany (NIAB); wheat breeders from Limagrain UK, KWS UK, DSV, Saaten Union UK, and Syngenta; and experts from the British Society of Plant Breeders. The extensive recorded interviews, which resulted in nearly six hundred pages of transcripts, followed an open-ended question structure.¹

The report is structured as follows. Section 2 provides a brief overview of the UK wheat industry to highlight the importance of wheat for British agriculture and the position of the industry internationally. Section 3 briefly discusses the major developments in the wheat research industry in the past century. Section 4 outlines “Transition Challenges and Solutions” which includes a discussion of government initiatives to re-establish UK leading positions in wheat research and breeding. Section 5 highlights the existing challenges the British wheat industry is currently facing, some of which are directly related to privatization of plant breeding. Building upon the UK experience, the final section, Section 6, describes the eight lessons for Canada, that can be drawn from the UK experience.

¹ The interview questions are provided in the Appendix.
Wheat is by far the largest crop in the UK. With yields of 8 tonnes per hectare and 15 million tonnes of wheat production, the UK produces about 2.5% of the world’s wheat on less than 1% of the world area. At 15 million tonnes the UK wheat sector is somewhat lower but comparable to CWRS wheat production in Western Canada. UK wheat production has tripled since 1960 with the most significant growth in both yield and area occurring between 1961 and 1990. This dramatic growth in wheat yields until 1990 reflects the adoption of the highly successful semi-dwarf wheat varieties developed at Cambridge PBI. Post 1990 the farm yields have stagnated and production has levelled out in the UK.

The Plant Breeding Institute (PBI) held a dominant position in the history of the UK wheat research/breeding industry for 75 years and helped Great Britain play a major role in global wheat research during the green revolution development of daylight insensitive, semi-dwarf wheat. Despite competitive pressures from foreign and local private breeding companies, PBI’s wheat varieties maintained about 80% market share from the 1970s and onwards. In 1987, PBI’s breeding programs and farm sites were sold to Unilever, a private food company. The sale of PBI ended public wheat breeding. A small wheat breeding industry had co-existed with PBI after the introduction of PBRs in 1964. Because PBI was large, well-funded, and very effective, private companies found it very difficult to compete with PBI. At the time of PBI’s sale each firm only had three or four percent market share while PBI dominated the market. Currently, wheat breeding programs in the UK reside with Limagrain UK Ltd., KWS UK Ltd., RAGT UK Ltd., and Syngenta UK Ltd. with the largest breeding programs being in the range of $1.5 million British pounds per annum.

The UK is a signatory to UPOV91 and has well defined Plant Breeders Rights (PBRs). The royalty rates on certified seed are set up by individual breeding companies. The royalty rate for all farm-saved PBR varieties is set at 52.5% of the previous year’s weighted average certified seed royalty, by an agreement of the National Farmers Unions and the British Society of Plant breeders. The royalty collection system operates effectively with little evasion by producers.

Despite the well defined PBR property rights and the effectiveness of the UK royalty collection system, total royalty revenue remains very modest in the UK. The 2010/11 total royalty income of £17 Million ($28 million) is about £1 per tonne produced. About one third of generated royalty income is re-invested back into breeding programs or about £6.3 million ($9 million) per year for the wheat sector, which is an average of $1.5 million over 4 major breeding programs. The limited size of royalties collected is a very significant constraint on the effectiveness of the private breeding industry. The limited investment could, in part, explain the limited growth in yields since 1990.
The sale of PBI and the relocation of some public scientists to other institutions, was accompanied with a watershed of change in science funding and the combination had a devastating impact on public wheat research. The Biotechnology and Biological Sciences Research Council (BBSRC) allocated funding to individuals and their institutions’ programs, on the basis of the citation rates and the journal impact factors of their peer reviewed publications. While this policy improved the scientific rigour of the work, it had a side effect of moving scientific effort away from applied wheat research toward more basic science on Arabidopsis and other model crops. The result was huge disconnect between what the public researchers could get funding for and what the private wheat breeding firms needed as input into their programs.

As outlined in more detail in the report, several interviewees refer to the early period of post privatization as “lost years”. One private researcher, although satisfied with the current system, felt the UK system lost 15 years of progress, by fracturing an integrated research system. Over the past decade, the public sector has made progress in developing funding systems and new institutions that provide incentive for public scientists and public institutions to undertake a portfolio of research that has long term commercial value for the industry.

In response to the efforts of the private sector to bring public scientists closer to plant breeding, the UK government launched a number of initiatives.

- **LINK program** created by the Department for Environment, Food, and Rural Affairs (DEFRA) was one of the first initiatives of the British government to bridge the gap between breeding and science. Within LINK, private breeders would collaborate with public researchers on research projects that had a direct relevance to industry needs.

- In 2003 DEFRA launched an initiative called the *Wheat Genetic Improvement Network* (WGIN). Meetings are organized every four months and are attended by researchers, breeders, and sponsors of wheat research including representatives of BBSRC, Home Grown Cereal Association (HGCA), and wheat breeding firms. By including a good cross section of wheat sector the WGIN can incorporate feedback right through the genetics to farming. The WGIN has been a rapid catalyst for getting breeders and academic people in the same room to talk about their common problems and after the review of a 5-year WGIN initiative it was decided that the government support to WGIN had to be continued and funding was extended until 2013 in the amount of almost £1.7 million over a five year period. The UK government is now looking into WGIN-3.

- **Crop Improvement Research Clubs** (CIRC) is program supported by the BBSRC: for every hundred thousand pounds raised by industry the BBSRC contributes nine hundred thousand to the ‘Club’. CIRC is £7.06 million, five year research partnership run by the
BBSRC, the Scottish Government, and a consortium of 14 leading biotech, grain, and oilseed companies.

- **LOLA/WISP pre-breeding program** is a publicly funded collaborative program between the UK academic and private sectors involving NIAB, John Innes Centre, Rothamsted Research, University of Bristol, University of Nottingham, and the private breeders who sit on the advisory board. The goal of the pre-breeding program is to have public researchers involved in the development of novel germplasm that can then be introduced by the private breeders into their elite lines. Germplasm developed in the pre-breeding program is publicly available and is free of IP.

The current role of the public sector in the UK is to undertake fundamental and applied research that can feed into private breeding programs. The centres of wheat research include two universities – the University of Bristol (Bristol) and University of Nottingham, and two research institutes – Rothamsted Research Limited (Harpenden) and John Innes Centre (Norwich). The research institutions are funded primarily by the government – BBSRC and DEFRA – with a very small proportion of research funding coming from the private sector either in cash or in-kind, farmer organization HGCA, and European Union. BBSRC funds about £14 ($23) million worth of wheat projects annually (Wheat Initiative, 2012). It supplies about half of the institutes’ funding through five-year programs called Institute Strategic Programs (ISP) grants and these grants form the core funding for the institutes.

Each of the research institutes and universities has distinct roles. The John Innes Centre has its strengths in crop genetics. Scientists at the Rothamsted Research come with agronomy and crop production background and the institute has built a strong scientific base in science of crop nutrition. Both institutes are involved in a recently established pre-breeding program, with John Innes Centre leading the genetics part of that program and Rothamsted Research performing the phenotyping and trait evaluation. The University of Bristol runs a wheat genome program where large scale genome sequences are generated and then released into the public domain so that the UK research institutes, the UK private breeding companies, and other players in the wheat industry globally can make use of the data.

Taking a snap shot of UK wheat research today, it would be easy to conclude that the UK sector made a smooth transition from public to private breeding, and operates small integrated wheat innovation system. However, the UK faced many challenges in establishing an integrated wheat innovation system and has only recently developed policies and funding processes that have allowed upstream public scientists to work with the downstream private wheat breeding industry. Understanding the situation that initially existed after the privatization of PBI, and the changes that were required to bring the innovation system to its current state, provide many lessons for
any country planning a similar journey. While they are reported in section 6, they are repeated here.

**Lessons for Canada: summary**

The privatization of wheat research in the UK provides many important lessons for Canada or any other country that is contemplating the privatization of wheat breeding. The outcomes, policy changes, and responses that have occurred in twenty-five years that have elapsed since the sale of PBI provide tangible examples of the outcomes from privatization of wheat research yielding lessons about measures that should be pursued and those actions that should not be repeated.

**LESSON 1:**

*If Canada intends to create a private industry with the scale and scope to be internationally competitive either IPRs must be much stronger than the UK 52.5% farm saved seed royalty, or additional funding mechanisms are required.*

The UK royalty collection system operates efficiently with coverage of more than 90% of the acres. Despite this extensive coverage, the pricing effect of the discounted farm saved seed royalty has kept royalty rates at low levels. The result is a very modest royalty stream generating $28 million in royalties of which, approximately $9 million dollars get reinvested in breeding activities, or about 55 cents per tonne of wheat produced. If Canada wants to create an intensive breeding system, this will require either property rights with even higher royalty rates on farm saved seed or a producer levy system, or both.

**LESSON 2:**

*Modestly sized private breeding industries require significant applied research support in order to be internationally competitive.*

The UK experience clearly illustrates that breeding firms with limited budgets cannot afford to make significant investments in plant science or crop science. While the UK government may have anticipated long-term public research savings, the recent level of reinvestment suggests that private breeding activities continue to require significant long term public support.

**LESSON 3:**

*If commercial breeding is removed from the public sector, mechanisms that maintain the linkages between applied public researchers and downstream breeding activities must be put into place.*
There was general view among the interviewees that the UK lost 10 to 15 years of wheat improvement by severing public researcher incentives to do applied crop science research. The UK learned the hard way that without incentives to do otherwise, competitively based science funding will attract public researchers toward activities with academic impact and away from applied research. If there are not clear incentives to work together the links between producers, private breeders, and public scientist weaken. As these linkages become weaker the knowledge flow is impeded, thus further reducing the effectiveness of the upstream public science research. The UK discovered programs that encouraged collaborative research and were quite effective in bringing public scientists and breeders together. Although it is also worth noting that some tension has continued to persist as the timeframe and reference points for public scientists and breeders differ.

LESSON 4:

*Government-mandated five-year funding blocks are a major impediment to long-term strategic research investments. Despite 25 years of post privatization experience, the UK continues to lack a long term strategic plan for wheat innovation.*

In the last 13 years, the UK government introduced many new research funding initiatives, (WGIN, LOLA, WISP, STB, etc.) each designed to foster wheat innovation. While these programs have brought much needed research resources to the sector, public researchers and the private breeders lamented the lack of a strategic plan and the inability to develop and fund long-term projects beyond the five-year commitment periods.

LESSON 5:

*Mechanisms to enhance knowledge sharing are important. Therefore, transition planning should develop policies to reduce knowledge and research fragmentation.*

The sale of PBI and subsequent downsizing resulted in four distinct breeding programs. Breeders’ rights, mechanisms to share germplasm, genomics research, and other upstream knowledge provide efficient knowledge sharing and keep breeders on a level playing field.

LESSON 6:

*The UK appears to have developed an efficient and effective two tier system of variety registration and recommended variety lists, which might have potential for application in Canada.*

Varieties must conform to well defined standards to achieve National Variety Listing. To be selected for Recommended Variety List, nationally listed varieties are subject to additional testing organized by HGCA and must meet stronger requirements. The UK national variety trials
are done with the participation of private breeders, which lowers costs and enhances knowledge sharing.

**Lesson 7:**

*Privatization of UK wheat breeding has made it more difficult to train crop scientists and crop breeders.*

The UK experience clearly illustrates that breeding and crop science are not a dichotomy. Good crop scientists need to understand breeding and breeders need to understand crop science. Although some training opportunities now exist, the removal of commercial breeding activities from public institutions has made it more difficult to fund and train students with the knowledge of breeding crop science. The public sector should be involved in at least pre-breeding so that scientists get hands-on experience.
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1. Introduction

Despite persistently high estimates of rates of return to agricultural R&D and the compelling evidence of significant contribution of R&D to increases in farm productivity (Alston et al. 2000), most developed countries have reduced the intensity of crop research and breeding (Pardey and Alston, 2010; Pardey and Alston, 2011). While some crops such as maize and canola have witnessed increased private investment to replace public funds, most have not. Given current economic conditions and budgetary pressures that most of the developed world including Canada are facing, it is unlikely that government support of agricultural R&D will be as generous as it was a half a century ago. To create and sustain a more optimal pace of innovation it is important to design an innovation system that can generate and sustain sufficient research investment. Learning from other countries’ experiences is essential to gain understanding of the merits and disadvantages of alternative research/breeding funding models.

Agriculture and Agri-Food Canada currently has plans to withdraw from wheat variety commercialization and shift the focus to upstream germplasm development activities (Jones, 2012). If there is going to be a transition toward privately funded wheat variety development, the important question is: “How can this be done in a way that maximizes the research potential of the wheat industry?”

The privatization of public crop breeding is often considered as a means to increase total research investment. However, privatization can also induce significant changes in knowledge sharing, research linkages, research networks, research practices, and other relationships, which are also very important for research outcomes. It is therefore important to fully understand these broader implications of privatization of crop research. Some of this understanding can come from examining the experience of other countries where privatization has taken place.

The UK restructured crop research funding by privatizing its public wheat breeding program. In 1987 Cambridge’s successful public Plant Breeding Institute was sold to Unilever marking an end to public wheat breeding in the UK. The twenty five years that have elapsed since the sale is sufficient time to be able to observe some of the longer run benefits and costs of privatization, to fully see what has worked well, and to understand what could have been done differently in the transformation from publicly funded to privately funded wheat breeding. Given their experience the UK is an excellent case study for examining the consequences and implications of wheat breeding privatization. The lessons that we draw from British experience can guide future policy initiatives for wheat industry in Canada.
The information and analysis presented in this paper are largely based on personal interviews with sixteen people involved in wheat research/breeding in the UK conducted during July 2012. The interviews reflect viewpoints of both public researchers and private breeders including wheat scientists from the University of Bristol, John Innes Centre, Rothamsted Research, and National Institute of Agricultural Botany (NIAB); wheat breeders from Limagrain UK, KWS UK, DSV, Saaten Union UK, and Syngenta; and experts from the British Society of Plant Breeders. The extensive recorded interviews, which resulted in nearly six hundred pages of transcripts, followed an open-ended question structure.

The report is structured as follows. Section 2 provides a brief overview of the UK wheat industry to highlight the importance of wheat for British agriculture and the position of the industry internationally. Section 3 briefly discusses the major developments in the wheat research industry in the past century. Section 4 outlines “Transition Challenges and Solutions” which includes a discussion of government initiatives to re-establish UK leading positions in wheat research and breeding. Section 5 highlights the existing challenges the British wheat industry is currently facing, some of which are directly related to privatization of plant breeding. Building upon the UK experience, the final section, Section 6, describes the seven lessons for Canada, which can be drawn from the UK experience.
2. Overview of the UK wheat industry

In 2011, the UK produced 15 million tonnes of wheat, which contributed £2.2 billion to the British economy (DEFRA, 2012). Wheat is by far the largest crop in the UK. Cereals occupy half of the UK croppable land (Figure 1), of which around 65% is sown to wheat. With yields of 8 tonnes per hectare and 15 million tonnes of wheat production, the UK produces about 2.5% of the world’s wheat on less than 1% of the world area.

![Croppable land use in the UK, 2011](source: DEFRA 2012)

**Figure 1. Croppable land use in the UK, 2011**

Although UK wheat production has trebled since 1960, the growth has slowed considerably (Figure 2). The most significant growth in both yield and area occurred between 1961 and 1990. This dramatic growth in wheat yields until 1990 reflects the adoption of the highly successful semi-dwarf wheat varieties developed at Cambridge PBI. Post 1990 the farm yields have stagnated and production has levelled out in the UK. This slowdown in yield growth coincides with the sale of PBI and the more recent restrictions on nitrogen fertilizer use.

The post 2007 increase in grain prices, combined with a contraction of the financial sector, has recently changed the attitude of the British government towards wheat. Wheat is now considered a strategic crop that warrants investment and has been placed on top of the list for the food security agenda. In June 2012 the UK government in collaboration with the research institutes
announced a new “20:20 Wheat” program with a goal to increase wheat yields in the UK to 20 tonnes per hectare from the current yield of 8 tonnes within the next 20 years.

The domestic use of wheat has also influenced the direction of research and breeding in wheat. The milling side of the market is driven by quality. The gluten strength has been major problem with the UK wheat. The work at Rothamsted Research institute in the 1970s-1980s looked at the role of low molecular weight glutenin subunits controlling gluten strength and the results of this work were used in the breeding programs. The result has been an increase in gluten strength over time, which is closer to meeting domestic milling requirements. As shown in Figure 3 the expansion of the area under wheat combined with increasing yields and quality has contributed to the UK gaining almost complete self-sufficiency in wheat. Currently, the UK produces slightly more quantity than is needed for domestic consumption; however, production of high quality wheat is not sufficient to meet the needs of the bread-making industry. While 80-85% of the wheat used by UK flour millers is home-grown, additional high protein bread-making wheat is imported, largely from Canada. About half of the UK wheat production is used as feed, and this part of the market is driven by yield.

Figure 2. UK wheat production, 1961-2010

Figure 3. Exports/imports of UK wheat, 1961-2009
3. The UK wheat research and breeding: historical notes and current roles

3.1 The Privatization of Wheat Breeding

The Plant Breeding Institute (PBI) held a dominant position in the history of the UK wheat research/breeding industry for 75 years. PBI was established at Cambridge in 1912 as part of the Department of Agriculture. In the early years, its work mainly evolved around development of improved wheat varieties with an emphasis on grain quality. After the Second World War there was a need to increase food production and research was considered an essential component to this end. As a result, in the post-war years funding to agricultural research centers in Great Britain was increased substantially and the breeding work at PBI was expanded to include barley, peas, maize, oilseed rape, and others.

PBI made a significant contribution to the UK wheat research and breeding industry and helped Great Britain play a major role in global wheat research during the green revolution development of daylight insensitive, semi-dwarf wheat. Despite competitive pressures from foreign and local private breeding companies, PBI’s wheat varieties maintained about 80% market share from the 1970s and onwards.

Despite PBI’s apparent success, the Thatcher government felt that it was not the government’s role to be closely involved in near-market research (variety development). In 1985 the Agricultural and Food Research Council proposed a policy that would re-organize British research institutes. The privatization of PBI crop breeding programs was one of the pillars of the proposed policy.

In 1987, PBI’s breeding programs and farm sites were sold to Unilever, a private food company. The units doing basic research on cytogenetics, molecular genetics, and plant pathology were excluded from the sale, and were later transferred to the John Innes Centre in Norwich. The commercial portion of PBI acquired by Unilever became known as the Plant Breeding International Cambridge (PBIC). In 1998, PBIC was sold to Monsanto, which was interested in wheat as a crop with high potential for application of genetic engineering techniques and development of hybrids. Strong consumer resistance towards GM wheat, and failed attempts to produce commercially viable hybrid wheat contributed to the loss of interest in wheat. Monsanto gradually pulled out resources from wheat research/breeding and sold the breeding unit to RAGT in 2004.

The sale of PBI ended public wheat breeding. A small wheat breeding industry had co-existed with PBI after the introduction of PBRs in 1964. Because PBI was large, well-funded, and very
effective, private companies found it very difficult to compete with PBI. At the time of PBI’s sale each firm only had three or four percent market share while PBI dominated the market. Currently, major wheat breeding programs in the UK reside with Limagrain UK Ltd., KWS UK Ltd., RAGT UK Ltd., and Syngenta UK Ltd. with the largest breeding programs being in the range of $1.5 million British pounds per annum. There are also a few small private companies involved in wheat breeding and these include DSV (Deutsche Saatveredelung AG) UK Ltd., Saaten Union UK Ltd., Blackman Agriculture Ltd., and some others. Figure 4 illustrates the contribution of the UK private breeding companies to the wheat industry in terms of the number of wheat varieties that have been released since the turn of the century.

**Figure 4. The number of varieties released in the UK in 2000-2011, by breeding companies**

In the past 20 years the private UK breeding industry has seen considerable consolidation. Changes and consolidations for the four major companies – RAGT, Syngenta, KWS, and Limagrain – are illustrated in Figures 5 through 7. Some interviewees expected more consolidation in the future, while others felt that the UK wheat market was pretty mature and expected no major changes in the next 10-20 years.
Figure 5. Establishment of KWS
Figure 6. Establishment of Limagrain
Figure 7. Development of Syngenta
3.2 Plant Breeders Rights and Royalties

The development of the UK private wheat breeding sector has been heavily influenced by the development and use of Plant Breeders Rights (PBRs). In this section we describe the development of UK PBRs in the context of international and EU agreements, how these property rights were used to develop an effective royalty collection system, which in turn has contributed to the development of a small, modestly funded private wheat breeding sector.

The private sector will only make breeding investments where there is a potential for income generation. For open-pollinated plants such as wheat or barley farmers have the physical capacity to buy seed and multiply it for future use. Without appropriate intellectual property rights the farmers’ ability to reproduce seed undermines the ability of the seed developer to generate enough rents through seed sales. To address this issue, almost all countries in the world have now adopted some form of plant breeders rights (PBRs) based on the principles of the International Union for the Protection of New Varieties of Plants (UPOV), an international agreement that encompassed 70 countries as of April 2012.

PBRs are intended to preserve the interests of both farmers and breeders. To this end, two exemptions are built into PBRs – the breeders’ exemption and the farmers’ exemption. The breeders’ exemption allows breeders to use any variety protected by PBRs in their breeding program without permission from the PBRs holder. Farmers’ exemption allows farmers to use harvested seed for subsequent reproduction on their own farm. To adjust to changing market conditions and to create stronger incentives for private investment, UPOV was revised in 1972, 1978, and 1991. Even though farmers’ and breeders’ exemptions are present in all of the revisions, in UPOV-91 the right to save seed is no longer an automatic right. UPOV-91 leaves it at the discretion of individual countries to decide whether to grant farmers the right to save seed. Countries that are signatories to UPOV-91 can also choose to collect royalties on farm saved seed.2 Western European countries except Italy, Norway, and Portugal have all adopted the 1991 revision of the UPOV.

In 1994, the EU passed legislation to become compliant with UPOV-91 that enables plant breeders to apply for EU wide protection of registered plant varieties. In this legislation, the EU allows breeders to charge a royalty on farm saved seed as long as it is sensibly lower than the royalty on certified seed.

The UK has revised its own PBR legislation a number of times to remain compliant with changing UPOV agreements and consistent with EU PBR legislation. This process began in 1964

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2 Although a signatory to UPOV-91, Canada still adheres to UPOV-78.
when the UK passed the UK Plant Variety and Seeds Act to become compliant with UPOV 1961. This act was amended again in 1983 to become compliant with UPOV-78. The 1997 Plant Variety Act was a significant change and contained provisions for royalties on farm saved seed making the UK compliant with UPOV-91 and consistent with the 1994 EU PBR legislation.

The EU and UK legislation provide for three different ways in which farm saved seed royalties can be collected. The first one is through a direct contractual relationship between the breeder and the grower, in which case the farm saved seed royalty is established between the two parties. The second one is through an agreement between a breeders’ association and a farmers’ association. If neither of the two options can work, then the third option is the default royalty rate on farm saved seed of 50% of that on certified seed.

Using the second option, the British Society of Plant Breeders (BSPB) has negotiated a contractual arrangement with the National Farming Union (NFU) setting a uniform royalty rate on farm saved seed. The royalty rate is set up through collective bargaining and negotiation between BSPB and NFU. The royalty rate on farm saved seed is currently set by formula to be equal to 52.5% of the weighted average royalty rate on certified seed grown one year before. This agreement combined with the provisions of the 1997 Plant Variety Act creates the legal framework for royalty collection in the UK.

3.3 The UK Royalty collection system

The British Society of Plant Breeders (BSPB) Ltd. plays a central role in royalty collection. All UK plant breeders are members of the BSPB. BSPB, which has been in existence for about 45 years, has four roles. It organizes variety trials, represents the industry, conveys information about the importance of breeding investment to farmers, and collects royalties.

The BSPB organizes both statutory trials, which are trials for variety registration, and non-statutory trials, which are used to develop recommended variety lists. BSPB acts as a focal point for technical discussion for the breeders at BSPB meetings with the industry and talking about technical issues relating to mostly how varieties are trialed. The Home Grown Cereal Authority (HGCA), which is funded by a producer levy, provides the resources for the non-statutory trials of registered varieties and, based on performance, publishes an influential List of Recommended Varieties for growers each year.

The BSPB also fulfils a representative role for the industry in relation to changes in regulations, trying to influence people. In this role, BSPB tries to see any changes in the regulations that are coming and assess the potential impact of those on the breeding industry. They work to establish
a common industry position on particular issues and put the industry’s case forward in the policy making process.

Royalty collection on cereals is the largest and foremost function of BSPB. It licenses the production and sale of certified seed of PBR protected varieties and collects the royalties; it also collects royalties on farm saved seed. For certified seed, BSPB has a head license with each of the breeders, which gives it the authority to act on the behalf of the industry in relation to certain varieties and then allow them to sub-license production and sales of seed of their varieties. BSPB also has about 160 sub-licenses for production and sales with seed merchants who produce and sell the seed and pay a royalty to BSPB. The collected royalties are dispersed back to the breeders with a small percentage of what is collected being retained by BSPB to pay the running costs of the society. The society operates on a not-for-profit basis and at the end of the year any surplus that has not been used is distributed back out to the breeders.

The current EU regulatory framework for certified seed is a conduit for easy and transparent royalty collection on certified seed. Every seed lot that is sold by seed merchants has to be inspected and certified, which is done by the National Institute of Agricultural Botany (NIAB) an independent, not-for-profit plant research and information centre based in Cambridge. Because every seed lot is officially registered; it gets a field number and a lot number and can be followed all the way through the system. This system makes the BSPB’s royalty collecting job a relatively easy one because they receive a declaration from each seed merchant which specifies how many tons of each variety they have sold and the royalty they owe; this information can easily be checked by matching up the merchants’ invoices for what they have sold against their official certification records. It was also mentioned during one of the interviews that the EU could deregulate the official seed certification system, which would make royalty collection more difficult.

The royalty rates on certified seed are set up by individual breeding companies and no cooperation is allowed in this regard. Information about royalty rates on commercial seed is kept confidential and is not shared between the industry participants in order to create more competitive environment.

The royalties for all farm saved PBR registered varieties are set at 52.5% of the previous year’s weighted average certified seed royalty, according to the BSPB/NFU agreement. The royalties collected by the BSPB on farm saved seed are paid to the breeders with the BSPB retaining about 10%, to cover the cost of running the program. The BSPB heavily relies on seed processors for collection of royalties on farm saved seed. About 80% of the farm saved seed money is collected for the BSPB by mobile seed processors. Mobile seed processors are typically firms that have a seed cleaning machinery on the back of a truck that go from farm to farm and
clean seed. When these seed processors invoice the farmer for cleaning and seed treatment they also invoice for the farm saved seed royalty at the same time, and they forward these monies to BSPB. In return, the processors are paid a small collection fee.

While paying levies on farm saved seed is a legal obligation, the collection of farm saved seed requires cooperation of farmers, particularly those farmers who clean the seed on their farms. The BSPB works closely with the NFU to promote the importance of royalty payments to support breeding. They also maintain contacts of all farmers who are contacted twice a year to remind them of the importance to support plant breeding and pay royalties. Because the royalty collection from farmers heavily relies on good will, the BSPB tries to avoid any measures that can be viewed as coercive. During one of the interviews it was mentioned that:

“We’ve never got to that point [of taking farmers to court for infringement]. I mean we’d prefer not to because the system works quite well. The farming unions are quite happy that we [the BSPB] take a reasonably pragmatic approach to life. If we start to get too severe and start taking farmers to court then, you know some of that good will which operates in the system at the moment is in danger of breaking down and we could actually be in a worse position. So I think it’s a very soft thing, so every year we get a little bit better. Every year we get a few more people back on the straight and narrow where they were. We’re just getting better and better all the time knowing them and knowing what they’re up to. You just have to take a decision on a case by case basis about how far you think you want to push it.”

Because the royalty rate on farm saved seed protected by PBRs is uniform across varieties, this generally eliminates the incentives to mis-declare varieties. However, there is still an incentive for farmers to mis-declare and report that they were growing some very old wheat variety that is royalty-free. To address this possibility, when the use of a royalty-free variety is reported, farmers are asked to provide seed samples for variety identification purposes.

The UK system has been successful at royalty collection because royalty avoidance and fraud have been low:

“The core of the wheat market, we put a lot of effort into making sure the system works with the farmers. The farmers understand they want plant breeding, they want to support plant breeding. They don’t resent paying. We’ve got support of the Farmer’s Union and it happens”.

Although it has taken many years for the system to become fully functional, the royalty collection system has a high compliance rate with low costs. Overall, the system gives the UK breeders the ability to collect royalties on virtually all certified seed and about 90% of farm saved seed. The administrative costs of the system represent only a small proportion of collected royalties: the BSPB only retains 1-2% of the royalties to pay for the costs of running the program for certified seed and about 10% to run the program for farm saved seed; and the remaining funds are returned back to the breeders.

### 3.4 Wheat Breeding Revenue and Research Investments

Despite the well defined PBRs and the effectiveness of the UK royalty collection system, total royalty revenue remains very modest in the UK. The 2010/11 total royalty income of £17 Million ($28 million) is about £1 per tonne produced. As shown in Figure 8, as new better varieties have been adopted over time, royalty rates have been increasing over time. Royalty rate on farm saved seed (FSS) was £36.1 per ton of seed in 2011, which is equivalent to £0.56 per ton of harvested grain. Because these FSS royalty rates are 52.5% of the weighted average of the previous year royalty rates on certified seed, this implies a 2010 weighted average royalty was about £68/t ($109/t). While these royalty rates have increased over time, one has to also keep in mind that wheat prices have approximately doubled since 2006, a further indication of a royalty system that does not generate a great deal of revenue.

About one third of generated royalty income is re-invested back into breeding programs. Although this rate of reinvestment is a higher proportion than for most other industry sectors, which is typically less than 10% (Webb, 2010), this research intensity reflects private breeding expenditures of about £6 million ($9 million) per year for the sector, or an average of £1.5 million over 4 breeding programs, with the largest programs at £2 million per year. As each of the firms indicated, they operate small breeding programs in the UK. Arguably the royalty structure of the UK wheat sector has failed to generate significant revenue for private wheat breeders and accordingly large investments have not occurred. Many firms also have strong linkage to breeding programs on the continent, which augments their effectiveness in the UK breeding resources. However, the limited size of royalties collected is a very significant constraint on the effectiveness of the private breeding industry. This underfunding could, in part, explain the limited growth in yields since 1990.

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3 Wheat seeding rate in the UK is about 120 kilograms per hectare or, alternatively, with one ton of seed a farmer can sow around 8 hectares. At an average UK yield of 8 tons/hectare, 64 tons of grain will be harvested for every ton of seed. This makes a royalty rate of £36 per ton of seed equivalent to £0.56 per ton of harvested grain.
The importance of royalties to build a strong private wheat breeding industry cannot be underestimated. The private sector still views a 52.5% royalty rate on farm saved seed as an element creating some underinvestment in the system and this is supported by a quote from one private wheat breeder:

“The one factor I think which actually interferes with the function of the free market is the situation with farm saved seed. I think the European regulation where farmers can go with farm saved seed and pay half the royalties, saying it is inequity is probably the wrong emphasis but I think it’s an artificial subsidy in the system”.

From an economic perspective any wedge between what a farmer is willing to pay for varieties and the benefits they receive from those varieties will limit the ability to generate revenue for private breeding. The ability of farmers to plant last year’s varieties as a farm saved seed and pay only 52.5% of the average royalty rate, severely constrains what any firm can charge for seed royalty on a new variety. As a result, new seed royalties must be conservatively priced in order...
to capture some market share. In turn, next year, 52.5% of these conservative seed royalty rates are reflected in the farm saved seed rate perpetuating the under pricing.

The combined effect of lower royalty rates and the 47.5% lost in farm saved seed provisions, means that UK farmers only pay $28 million in royalties, a very small faction of the benefits they receive from new varieties. In contrast to these weak property rights that exist in the UK, the Canadian Canola research industry is protected by patents and the strong property rights of hybrid technology. This private industry earns an estimated of $578 Million (23 times as much as UK wheat) in gross margin from the sale of varieties and invests over $65 million per year (eight times as much) in breeding activities (Gray 2012).4

In 1987, the UK government assumed that if public research funding was cut and some research needs were not met, the private sector would take over and invest heavily. But it never occurred because the royalty revenue base was not there. The involvement of industry in funding wheat research is only marginal and this is supported by the following quotes:

“The wheat breeders in the UK are very poor because of the royalty scheme on the seed and so they really are maxed out on how many projects that they can fund and that is one of the bottlenecks to the sector going through breeding. As a result, I can’t believe that they are even funding, in total value, ten percent of the actual total funding, it might be even less than that. They might be involved in a lot of projects but they’re each putting in a very, very small amount - ten thousands, two thousands, or in kind.”

“In terms of wheat research, they [the private companies] fund almost no research which is not directly related to breeding. In the private sector we work with two groups of plant breeders and they will support their own plant breeding programs and they carry out a very small amount of research, almost negligible.”

The ability to generate income drives research investment on the part of the private sector. Research is usually very risky and not profitable in the short run. Small private companies cannot afford to invest into initiatives that might bear fruit 15-20 years down the road. Perhaps why Monsanto and Syngenta have been in and out of wheat research in the UK over the last decade was a hope for application of genetic modification in wheat or the potential development of

4 On the other side ledger with no farm saved seed royalties at all, the Canadian wheat breeders earn only $3 million per year in royalties – far less than in the UK.
commercially viable hybrids. When it became clear that there was a thick legislative wall and wheat once again proved to be non-responsive to hybridization, these large companies withdrew their resources from wheat. As we discuss in section 4, the ability for wheat breeding firms to leverage applied public research has recently induced small amounts of private research in the UK.

3.5 The role of upstream public sector research

The sale of PBI and the relocation of some public scientists to other institutions were accompanied with a watershed of change in science funding and the combination had a devastating impact on public wheat research. BBSRC allocated funding to individuals and their institutions’ programs on the basis of the citation rates and the journal impact factors of their peer reviewed publications. While this policy improved the scientific rigour of the work, it had a side effect of moving scientific effort away from applied wheat research toward more basic science on Arabidopsis and other model crops. The result was huge disconnect between what the public researchers could get funding for and what the private wheat breeding firms needed as input into their programs.

Several interviewees refer to the early period of post privatization as “lost years.” One private researcher, although satisfied with the current system felt the UK system lost 15 years of progress, by fracturing an integrated research system:

“I think we probably lost 15 years of research to be honest. …With these various research integrations that are going on now, we pretty much got back to where we were 15 years ago I guess when those public breeding programs were privatized. And I don’t think we’ve gained anything over that period of time. In fact as an industry generally, I think. I mean clearly some companies have probably gained but as an industry, in terms of genetic advance, genetic gain, no, I don’t think we have.”

Over the past decade, the public sector has made progress in developing funding systems and new institutions that provide incentives for public scientists and public institutions to undertake a portfolio of research that has long term commercial value for the industry. Given their importance the policy measures used to connect public researchers with private breeding industry are described in more detail in Section 4.

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5 This shift toward model crops was also driven by earlier gene mapping and the relative simplicity of these model crops.
The current role of the public sector in the UK is to undertake fundamental and applied research that can feed into private breeding programs. The public sector is looking for variation in traits, making synthetic wheat lines, and alien introgression. The centres of wheat research include two universities – the University of Bristol (Bristol) and University of Nottingham, and two research institutes – Rothamsted Research Limited (Harpenden) and John Innes Centre (Norwich). The research institutions are funded primarily by the government – BBSRC and DEFRA – with a very small proportion of research funding coming from the private sector either in cash or in-kind, farmer organization HGCA, and European Union. BBSRC funds about £14 ($23) million worth of wheat projects annually. It supplies about half of the institutes’ funding through five-year programs called Institute Strategic Programs (ISP) grants and these grants form the core funding for the institutes. Until recently wheat was not the main feature of the ISPs, however, this is rapidly changing with wheat given a central place in the new strategy for 2012-2017 through a launch of the “20:20 Wheat” program.

The institutes compete with the universities for BBSRC’s Responsive Mode grants that comprise about 20% of the institutes’ funding. Responsive Mode grants are very competitive but they provide an opportunity to the researchers to work on some aspects of research that are of particular interest to them.

DEFRA used to be an important player in funding wheat research but has moved away from it in recent years. For example, the share of DEFRA funding in the Rothamsted Research’s total funding decreased from 50% in the mid-1970s to about 10% currently. Overall, currently DEFRA funding amounts to about £2.4 million annually. Some interviewees suggested that the name change of the Ministry of Agriculture to DEFRA demonstrates that there has been a shift in the interest from agriculture to rural economy and environmental protection.

Each of the research institutes and universities has distinct roles. The John Innes Centre has its strengths in crop genetics. Scientists at the Rothamsted Research come with agronomy and crop production background and the institute has built a strong scientific base in science of crop nutrition. Both institutes are involved in a recently established pre-breeding program with John Innes Centre leading the genetics part of that program and Rothamsted Research performing the phenotyping and trait evaluation. The University of Bristol runs a wheat genome program where large scale genome sequences are generated and then released into the public domain so that the UK research institutes, the UK private breeding companies, and other players in the wheat industry globally can make use of the data.

Taking a snap shot of UK wheat research today, it would be easy to conclude that the UK sector made a smooth transition from public to private breeding, and operates small integrated wheat innovation system. However, the UK faced many challenges in establishing an integrated wheat
innovation system and has only recently developed policies and funding processes that have allowed upstream public scientists to work with the downstream private wheat breeding industry. Understanding the situation that initially existed after the privatization of PBI, and the changes that were required to bring the innovation system to its current state, provide many lessons for any country planning a similar journey.

4. Transition Challenges and Solutions

4.1 Introduction

While privatization of breeding activities significantly transformed the UK wheat research/breeding industry, it yielded several unexpected outcomes. On the basis of the theory of public goods, one could potentially defend privatization of near market research (breeding) and the decision of the government to leave only pure science (basic research) in the public domain. However, the UK experience reveals that this naïve approach had disastrous consequences because it ignored applied research that was required to link discoveries of basic science to the needs of a small private breeding sector.

In this section we outline, several of the programs and initiatives introduced to better align the interests of public researchers and private breeders for the betterment of wheat innovation in the UK.

4.2 The Post-Privatisation Research Gap

A system where public sector is responsible for wheat research and the private sector is responsible for wheat breeding may seem like a good strategy to establish a strong wheat industry. The UK experience, however, proves that this approach can actually significantly undermine a country’s leadership position in wheat research/breeding if the roles of the public and private sector are inappropriately assigned.

When PBI in Cambridge was privatized and some of it moved to the John Innes Centre in Norwich the link between the commercial breeding sector and upstream public research was broken. Despite the fact that the private companies employed PBI-trained personnel and everybody in the industry knew each other, the scientists and the breeders drifted apart. In the late 1990s - early 2000s the UK wheat research/breeding industry was in the abyss with a total disconnect between upstream public research and breeding. As one interviewee indicated:
“It was called valley of death, there was no way of connecting basically the industry part of the research with what was going on in academia and a lot of academia has also left the crop species and had gone to Arabidopsis at the time as well [as it was easier to make breakthroughs in Arabidopsis as a model crop and publish].”

Part of the gap was created by new public research funding policy. When the decision to privatize breeding was made, the UK government thought that the role of the public sector was to advance biological science and the government did not see the importance of its involvement in funding applied research. After privatization of PBI, the structure of government funding changed such that public research grants were competitively awarded based on the academic impact factor of the researcher’s publications or in other words, excellence in science. Publication in high-ranking science journals became a prerequisite for public researchers to win competition for public money. The need to publish contributed to a shift from commercial crop research to model species (Arabidopsis) research and moving academia further away from research that was of relevance to the private sector.

One interviewee also suggested that another factor that contributed to widening the gap between science and breeding was that public scientists believed that genetic modification (GM) research was going to have a significant impact so the emphasis changed to what the large biotech companies were doing:

“If you believe that models were going to be the main way we had impact, then that was going to be through GM and it was going to be with the large bio-tech companies. So, your emphasis moved away from the smaller companies to those models”.

All respondents described the first fifteen years after privatization of wheat breeding as the road to nowhere. These are some of the quotes from the interviewees:

“A few years ago there was quite a lot of frustration that the academic sector and the funding that they were getting was being driven by considerations that were not relevant to plant breeding …the big problem for us [private companies] was there was a division between plant science and crop science and a lot of the research that was going on was just out of reach of plant breeders. It was plant science not crop science. A lot of it was in model species and so on. It was just out of reach for what we [private breeders] were doing.”
“I think both in wheat and in rape research (the two areas I'm most familiar with) a lot of the research going on at John Innes and Rothamsted was getting really too far away from the type of research that we [private industry] would be interested in picking up and running with. I mean very sort of basic research that does need to be done. But there was too much emphasis on basic research and not much on near market research”.

“…we’ve been working together the last fifteen years, we really recognized the big gap in any applied research. There was a lot of work in the 90’s on Arabidopsis, some great fundamental work going on in the UK, brilliant papers coming out and we were seeing nothing being translated into anything useful in the cereals”.

It has taken the UK wheat research industry almost twenty years to close the applied research gap created by privatization. Currently the industry has returned to where it was prior to privatization in terms of research potential and breeding outcomes; however, without significant public investment into creation of public-private consortia, re-establishment of public pre-breeding programs, and other initiatives discussed next this return would not have been possible. Given the vital importance of these initiatives, each is described below.

### 4.3 DEFRA wheat research funding initiatives to reconnect science and breeding

With a brutal split between basic and applied science, the private sector could not successfully develop without support from the public sector in terms of generating knowledge that was relevant to the private wheat breeders. In the early 2000s, the major private breeding companies created an organization called British Wheat Breeders, whose role was to influence where the public money was invested and direct it into projects that were more useful and more accessible to the plant breeders. This role has recently been assigned to the British Society of Plant Breeders (BSPB) that tries to “get funding in public research near enough to plant breeding so that we [private companies] can actually tap into it, not tap in and get cash, but tap into the research that is being done by the public sector and utilize it”.

In response to the efforts of the private sector to bring public scientists closer to plant breeding, the UK government launched a number of initiatives. LINK was one of the first initiatives of the British government to bridge the gap between breeding and science. Within LINK, private
breeders would collaborate with public researchers on research projects that had a direct relevance to industry needs. LINK projects were supposed to be led by their private sector partners, with the research supported through the provision of grants, typically up to 50% of the total project cost. As a rule, the private sector had to contribute 50% of the total project cost either in cash or in-kind, with in-kind contribution being preferred most of the time. In-kind activity would generally include providing germplasm, doing some molecular marker work, running field trials or testing for quality. Most of the direct public funding for the initiative was coming from DEFRA with a small proportion coming from BBSRC. Because research projects within LINK meant to be industry-driven, the premise was that public research would be of high value for the industry and would translate into improved new crop varieties. The interviewees described LINK as a real success to get the wheat breeders and scientists talk to each other even though very often the projects were driven by academics rather than the industry:

“The way it [LINK] was meant to work on paper was industry has a problem, find academic to solve the problem, provide 50% in kind and then academic goes to the ministry for the other 50%. The way it actually worked was that academics identified the opportunity and funds and then would come and say “Can we work together on a particular topic?” and we would agree and that’s how they would secure the funding.”

Some interviewees indicated that raising money from the industry as the requirement of the LINK initiative is not easy sometimes, which can limit the success of such initiatives:

“In my view it [DEFRA LINK project] really helped to bring industry and the public together. It did have some issues, very difficult to find that 50% of funding and I think in the projects we worked on in LINK we always over-delivered but simply because the 50% that comes in cash is never quite enough.”

“So, for LINK if you can put together a package where the industry agrees to spend half the cost in-house, we can get matching from the BBSRC for the other half. But it’s very difficult to get together. You need large consortia, there are big IP problems with them and it’s a painful way to get money actually”.

To preserve the interests of the private sector, in the LINK projects everything was done behind closed doors with generated knowledge being confined to a circle of project participants.
Realizing the importance of information sharing, IP protection strategy was abandoned in later initiatives by the UK government.

Seeing the benefits of improved communication between the public and private sectors through the LINK project and realizing the importance of boosting wheat yields through genetic improvement, in 2003 DEFRA launched an initiative called Genetic Improvement Networks (GINs) that covered various crops of importance to the UK agriculture. At the core of the Wheat Genetic Improvement Network (WGIN) is funding of some £370,000 per year over 5 years, about half of which is spent by Rothamsted. It paid for germplasm evaluation, new technologies and tools, and stewardship of a germplasm resource. The researchers work on how to select for disease resistance, acquisition and characterisation of pathogen germplasm, and the development of an information base. Around this core are satellite projects, which receive £1.6 million of funding per annum, and which both inform and benefit from the core activities and strategies of the WGIN (Little, 2004).

The WGIN represents a broad range of interests. Meetings are organized every four months and are attended by researchers, breeders, and sponsors of wheat research including representatives of BBSRC, HGCA, and wheat breeding firms. By including a good cross section of wheat sector the WGIN can incorporate feedback right from the genetics through to farming. The WGIN has been a rapid catalyst for getting breeders and academic people in the same room to talk about their common problems and after the review of a 5-year WGIN initiative it was decided that the government support to WGIN had to be continued and funding was extended until 2013 in the amount of almost £1.7 million over a five year period. The UK government is now looking into WGIN-3.

Realizing the importance of information sharing, one of the requirements of the WGIN project is that all of the IPs created within the scope of the project are free of IP protection. All findings must be made publicly available as soon as they come. The benefits of free sharing of information have been acknowledged by all of the interviewees:

“In fact I can say that this model [IP protection-free model] has actually led to enormous proliferation and use of the data in other projects. After the first years of funding we enjoyed fifteen million pounds worth of wheat projects extra funding because this is all in the public domain, not protected by IP and it was eight million when we did it the first time so that’s already twenty-three million pounds worth of new funding in wheat from our initial start of under four million. You would not have had that if it was all IP-protected.”
The IP protection free model has also been an important incentive for the private sector to get involved in collaborative projects with the public researchers:

“… if we [private firm] are going to participate in a project we do so pretty openly and what’s important for us is to be in the agreement that we can use the output from the project without having to turn around and pay a lot of fees.”

Even though free sharing of information might not be in the best interest of the industry as they would like to have research lead and withhold some information early in the game, having industry partners involved in research projects with public researchers does not seem to have restricted information sharing in the UK wheat industry:

“…the contracts say it but it’s sort of the unwritten rule as well…that if you’re in the project you’re in it because you’re going to get real lead time over the guys who are not in the project. You understand that the academic is going to publish but perhaps he’s going to finish the project and publish in a year time or two years time. Equally, I mean the contract may say that but equally I’ve seen it on a number of occasions where you got something which is quite interesting and the guy wants to publish and do something pretty quickly before he loses advantage. They come back to the consortium and say “Can I publish it?” and the industrial guys might say “Can you take out a little bit of detail?” but in principle they let them publish it. I don’t think it’s restrictive at all.”

4.4 The Technology Strategy Board

LINK funding by DEFRA has declined significantly over time. The DEFRA link programs have now largely ended and they have partially been replaced by what is called the Technology Strategy Board, which came out of the old Department of Technology and Industry and has worked extremely well in certain sectors of industry, particularly in the pharmaceutical industry. The Technology Strategy Board helped Rolls Royce and the car industry to achieve great success and the idea of moving really good research results in crop research through to market place seemed appealing. There have been a series of calls with targeted themes in crops; however, some of the interviewees acknowledged that the Technology Strategy Board initiative is not really working in agriculture given the longer term nature of crop research:
“…the first thing that happened when they [the Technology Strategy Board] started to get into agriculture was there was nobody with any knowledge on agriculture at all even though they were going to start on funding. So they had to appoint people and they appointed two or three people and it’s all grown but initially they were trying to fund things for agriculture and had no idea what agriculture was or how it worked and it caused quite some problems because the expectations they had on industry funding of things was a lot higher than the industry could actually manage to do. It’s sort of moved a bit over time but it’s still quite a difficult mechanism to work with.”

“There’s a very interesting element of it [the Technology Strategy Board funding] which really should be very good from an industry point of view; it is a strong emphasis on the actual stream of applications and how it’s going to fit into a business plan. Actually commercialize, right down to the level of coming up with some estimates on the likely potential income to be generated, you know, returns from investment, which should be really useful and sensible for industry. But for us in the breeding industry it’s extremely difficult to make predictions of what, how an investment in a particular area will flow. We’re finding it very hard to meet their requirements for feedback in this area because it’s so based on relatively short time frames ideally from their point of view, whereas our time frames are quite substantial. We’re looking for having some return maybe in 10-years time from a bit of work that we’re doing now and this is very hard to put tangible business plans with numbers on them. We can put a business plan in the general sense but not always with numbers.”

4.5 The BBSRC Crop Improvement Research Clubs

At the moment the major funder of wheat research in the UK is the BBSRC that has taken over the funding role of DEFRA and provides funding for projects that engage public researchers with the industry.

Seeing how well the DEFRA networks were working, in 2006 BBSRC started to put in some funding for a network called Monogram. The purpose of this network was to strategically align
the cereal and grass genetics and genomics research in the institutes under a single umbrella. From there, other new events linking industry to the academics started to emerge. One important initiative is the creation of Crop Improvement Research Clubs (CIRC). Club funds are leveraged by the BBSRC: for every hundred thousand pounds raised by industry the BBSRC contributes nine hundred thousand to the ‘Club’. CIRC is £7.06 million, five year research partnership run by the BBSRC, the Scottish Government, and a consortium of 14 leading biotech, grain, and oilseed companies. The first call only featured two wheat projects. The second call for projects within the CIRC came out in 2011 and in the second call there are now four wheat projects going forward. To ensure a close link of the CIRC projects with the industry needs, the projects are refereed and led by the industry.

The BBSRC recent initiatives have been facilitated by a change in attitude towards science. The BBSRC original target was scientific excellence, which slowly transformed into “excellence with impact” and the question that the government asks today is “What are public researchers delivering for the industry?” A lot of this change is the result of the private sector trying to influence politicians in how to invest research dollars more effectively.

Due to all of the initiatives discussed above, close partnerships between the public researchers and private breeders have been established. With the elimination of competition from the public sector in the area of breeding, public-private partnerships started working really well in the UK. These are horizontal rather than vertical partnerships, however, where private breeders and public researchers discuss issues around the table as allies rather than competitors. These initiatives have also promoted public-public and private-private collaborations.

A key to establishment of successful public-public collaborations was a clear division of the roles of the public institutions. In the past, for example, BBSRC would encourage a lot of competition among the research institutes and would fund research projects that were duplicative in nature. The idea behind public scientists competing in research was that competition could result in first-class science. In recent years the structure of the funding has been changed so that public research is complementary; scientists work together in different initiatives and research institutes have distinct roles in those.

Partnerships are considered an essential component for the success of plant breeding. An interesting point that ran through the interviews is that a system of horizontal public-private partnerships where both sectors are engaged in breeding would not work. The interviews with the UK private wheat breeders reveal that in the long-run such vertical partnerships are difficult to sustain. The UK experience is unique in a sense that there are vertical rather than horizontal linkages between the public and private actors. The public sector complements the private sector:
with the public sector doing research and with breeding activities residing solely within the private domain, the public sector does not compete with commercial breeding. As was indicated by one interviewee vertical partnership is the one that comes naturally and can work smoothly if there is sufficient public investment to link the two sectors. However, if breeding is performed both within the public and private domain, competition will be on the way to successful partnership.

“I think we [private companies] view the finishing of the varieties to produce the product for the farmer as a very focused operation to take whatever tools, whatever breeding material, whatever methods have come from basic research, some earlier research but there has to be a breeding team which can really focus on delivering the finished variety, understanding what they’re producing, getting it right for the right market places out in the farms and I don’t think we would like to see that part of the job going to the public sector in Europe. I think we would see that as a real imposition on the relationship we have to the public research work that is going on and it would concern us that there would be competition between us. …if there was a private and public company and public breeding program and us [private company] and we were asked to sit down and think about future targets and what research should be done it’s a disincentive if you think”

4.6 BBSRC LOLA/WISP - Pre-breeding Programs

With privatization of plant breeding in the UK, the development of elite lines went into the private sector, while a broad scale developing of pre-breeding material almost stopped. Pre-breeding activities fell outside of what the private sector was willing to do as these activities are considered long-term, risky, and generally not yielding sufficient rewards. At the same time there was a recognition that the wheat industry could benefit from having a pre-breeding program. The wheat breeders wanted to increase diversity in their breeding programs by introducing novel trait; at the same time the public scientists had identified a number of the key traits which were targets and there was a need to dissect the next generation of traits which might involve yield and some nitrogen uses. In order to do that, pre-breeding material had to be developed. In the late 2000s, in collaboration with the industry a proposal was developed and submitted to the BBSRC to establish a public wheat pre-breeding program in the UK. In February 2011 BBSRC
announced a £7 mln. grant to a consortium of researchers to increase the diversity of traits available in wheat via a comprehensive pre-breeding program. This initiative became known as Long and Large (LOLA)/Wheat Improvement Strategic Programme (WISP). The second tranche of funds was announced in 2012 for a total of £16 mln. over six years for two tranches of funds.

LOLA/WISP pre-breeding program is a publicly funded collaborative program between the UK academic and private sectors involving NIAB, John Innes Centre, Rothamsted Research, University of Bristol, University of Nottingham, and the private breeders who sit on the advisory board. The breeders inform the public scientists of their needs, so there is a direct link with the industry, but they do not contribute any cash to wheat pre-breeding. The goal of the pre-breeding program is to have public researchers involved in the development of novel germplasm that can then be introduced by the private breeders into their elite lines. Germplasm developed in the pre-breeding program is publicly available and is free of IP.

The pre-breeding program has three core germplasm development activities. There is an agreement that all the material be crossed to a single elite spring wheat variety and this is an important element of the pre-breeding program to ensure that it is not competing with the UK winter wheat breeding programs. The first core activity of the pre-breeding program involves the use of landraces from the Watkins collection held at the John Innes Centre. The main goal of this activity is to increase diversity. The second core activity is funded at the NIAB and it is a synthetics wheat program. The third core activity is an alien introgression program established at the University of Nottingham. The target traits in the program are yield, nitrogen utilization, phosphorus utilization, blowfly resistance, and aphid resistance.

The NIAB is a key player in the pre-breeding program. It should be mentioned that NIAB is a not-for-profit organization and, therefore, it does not receive a core funding from BBSRC that the research institutes enjoy and, therefore, it is much harder for NIAB to raise money for pre-breeding activities. The work on synthetic wheat is funded by BBSRC. Within this program, they recreate wheat from its progenetive species and do genotyping by sequencing to mine out novel known genes and also to identify novel genes. They are also involved in modelling plants and map development. The work on synthetic wheat provides a lot of information to the commercial sector about the adaptation of material and its usefulness; however, it is still a large step away from being directly utilized in commercial breeding programs. The UK Limagrain, KWS, and RAGT firms have formed a consortium to fund follow-on pre-breeding activities where NIAB incorporates the results of the preliminary breeding work into the companies’ breeding programs by back-crossing synthetic wheats into elite germplasm. The germplasm developed in this follow-on pre-breeding program is proprietary and is kept within the boundaries of the consortium of the three companies. This germplasm has to be released into the public domain
eventually because the work is built upon publicly funded synthetic wheat program; the companies are given a number of years to have capitalized on that novel germplasm before it is made publicly available.

As was indicated by all private breeders, re-establishment of pre-breeding activities within the public domain has significantly facilitated private breeding and has allowed research results to find their application in breeding faster. The interviews suggested that if a split between private and public is made it is important that pre-breeding remains in the public domain, otherwise the link between research and breeding will be broken as there is not enough money in wheat for private companies to pay for pre-breeding activities. One private breeder suggested that an alternative system that could be successful would involve public investment in pre-breeding with private companies contributing to partially cover the cost of pre-breeding after their varieties developed using the pre-breeding material had been commercialized and yielded some royalties:

“The critical thing really I think is that the pre-breeding needs to be free of cost as far as we [private breeders] are concerned. We would be more than happy if some royalties that would come once we’ve got a commercial variety at the end of it go back to the organizations that are doing some of the pre-breeding work, which is pretty much the way INRA have done it with the their royalty system in oilseed rape and I think if we have a similar system here with whatever research is going on then I think it could work reasonably successfully.”

4.7 Enhancement of Variation in Wheat Germplasm

In recent years there has been increased recognition of the importance of investments into infrastructure to support the mission of being able to fulfil research initiatives. Currently, there is much more involvement of BBSRC into maintaining biological resources underpinning the research community. The major national collection is at John Innes Centre and although it has taken many years to raise awareness of germplasm collections, it now enjoys full cost funding from the BBSRC. Some funding is also coming in from DEFRA but the DEFRA funding is primarily for the pea collection.

It should be noted that investment in germplasm collections is particularly important now that the cost of genomics research has decreased significantly; as was indicated by one interviewee “it [genomics technology] is becoming more reliable and cheaper you are able now to actually genotype whole collections… this is making germplasm collections much more relevant”.
Germlasm collections are an integral element of the whole research-breeding system as they are the source of diversity.

The BBSRC funding does not only cover the cost of organizing the collection but a strong emphasis is placed on engagement of the collection curators with the community. It is the curators’ role to respond to requests about particular lines held in the collection as well as advise researchers/breeders what lines are appropriate to study a particular trait. To raise awareness of the research community, ‘growing demonstrations’ are periodically organized. These demonstrations present a kind of visual genotyping; they are targeted at breeders and researchers that come to view the material, talk about the material, talk about the penetrance of genes and their ability.

4.7 Private Breeder Collaboration in the National Variety Trial System

As was mentioned earlier, there has always been some collaboration among private breeders in the UK due to the nature of the variety testing system and more so due to recent funding initiatives. In order to market any variety in the European Union plant breeders have to go through one of the national testing systems within one of the 27 member states. The UK breeders normally put their varieties through the UK variety testing system. The British Society of Plant Breeders (BSPB) operates under a license from the national authorities in the UK to organize the variety trials. Even though wheat trials are organized by the BSPB, most are contracted out with breeding companies and places such as NIAB.

Typically breeders use their own pre-screening trials to identify promising varieties that are entered into national testing. Breeders are charged a fee to put their varieties into trials, however, the fees are set just to cover the cost that the BSPB incurs to operate the system. Given that trials are contracted out to the breeders, the system is very cost effective as the breeders can run these trials at marginal cost because they are running thousands of plots anyway. In addition, the trial system gives a chance to the breeders to see everybody’s material, which is highly valued within the breeding circle. Through trials, the breeders can see what all the competitors are producing and putting in “so every breeder wants to have one of those trials on their home patch so they can get a good look at what is going on with the opposition”.

The institutional changes were also required for cost saving:

“When you come to the National Listing part the registration part in UK we’ve had fairly radical changes over the last ten fifteen years and
I think there’s more changes happening now and the system used to be that plant breeders submitted their varieties to the NIAB effectively to the agent of the state and they tested them and the government paid for the testing and the varieties were put on the market and we’ve had fees progressively increased; they always talked about full cost recovery so fees were introduced and fees were increased and now we’re in the final stage of having all the costs thrust onto plant breeding. The way we dealt with that because the cost would have been astronomical, was to organize a series which we called the BSPB trials. Those trials have two functions now, I mean for a long time they were just grown by the breeders and nobody was using them because they were not official and all that nonsense. We got past that so those trials are now grown under license for the Ministry. So from the Ministry’s perspective they’re licensing us to grow the registration trials. From the industry’s perspective the Ministry’s is using the trials that we were already growing.”

The testing goes on for two years and the aim is to see whether a variety has value for cultivation or use. In order to be added to the national listing, the variety needs to show significant benefit in some defined area and some defined area. Yield is the main criteria and it is largely yield with fungicide treatment, which is the main driving factor. Alternatively, the variety could have better disease resistance to some pathogen or could have a significantly better quality for wheat for specific bread making purposes, specific biscuit making or go for distilling. If yield is not the defined characteristics, the testing authorities have to be informed that the variety may have a slightly lower yield but outperforms the existing varieties in a different area. The variety then enters trials under a separate category with additional tests run to prove or disprove the claim that the variety outperforms in the mentioned area. If the claim is upheld, the variety is added to the national list. The trials are coordinated by the BSPB and the data set that comes in from those trials goes off to the national authorities who use it to make the national list decision. Each year there are about 40 varieties that make it to national list year, with between 8-12 lines going on to the recommended list trials.

Once varieties are added to the national list a series of committees are organized and funded through the HGCA, which take decisions of which varieties can go onto the recommended list trials. The HGCA typically has 26 trial sites. Only the varieties that have substantial merit in comparison to the controls are selected for the recommended list. The recommended list states
that you have to get 2% higher than the current yield potential. If it has special attributes then they will accept something that is the same as or maybe 1% lower but generally higher than what is already on the market. This list is a valuable independent source of information for farmers with only a few varieties making it to the recommended list. For breeders, making it on to the recommended list is critical for the commercial success of a variety.

4.8 Summary

Summarizing the above, overall public funding of wheat research in the UK has increased in the last years and as was mentioned by almost all of the wheat researchers “it has never been better”. There has been a positive change in the government’s attitude towards crop science when the world got hit by the financial crisis:

“In the pre-financial crisis period, this was never laid down as policy, but things were like “We don't need farming in the UK, we’ve got the city of London and we’ll import wheat from Canada”. You know that was pretty much close to policy and as soon as we started getting global food security crisis it was revealed that the city of London wasn’t as solid as people thought it was then we got that shift [in public funding] as well.”

An interesting fact that the interviews have revealed is that by privatizing crop breeding programs the UK government sought to diminish its role in funding crop research and breeding via delegation of more responsibilities to the private sector. However, fifteen years down the road, when it became clear that lack of public support had significantly undermined leadership positions of the UK in crop research it had to reconsider its role and significantly boost research funding.

One lesson that one can learn from the UK experience with wheat research is that, if ways are sought to reduce a pressure on the government budget, privatization of breeding may not be a panacea. On the contrary, breaking the pipe-line and going from a model where both research and breeding are performed at one public site to a model where breeding is performed by the private sector and research is performed by the academic sector may require increased investments on the part of the government to establish and maintain the link between the two. With increased public involvement in wheat research, “the government research that was lost in places like PBI is now being slowly replaced”.

5. Existing challenges in the UK wheat research model: qualitative evidence

5.1 Training of new generation scientists and breeders

One of the advantages of having both research and breeding in the public domain in the UK was a close link between what was happening in laboratories and what was happening in the field. When PBI was in place, the system was characterized by a high degree of integration and as a result it was successful in producing new scientists and breeders. As was indicated by one private breeder: “The strength of the PBI was that it pumped out scientists and breeders that were very influential”.

With privatization of breeding and subsequent alienation of research institutes and universities from what was happening in the field, training of plant breeders has become an issue. The number of wheat scientists/breeders that the system has produced has decreased significantly. Currently, almost all of the wheat scientists and breeders are either approaching their retirement or will retire in 10 years or so. The system is not prepared to replace the retired scientists with new generation scientists, which puts the whole wheat research industry in jeopardy:

“Training of crop scientists is a major issue. There has been shrinkage of agricultural departments in universities for decades now in Britain and also a lot of universities have lost their farms and they’ve lost their practical staff. As a consequence it became quite noticeable even in the late 1990s that if you wanted to do crop science research you were left with the institutes and a very few universities. …if you want to have crop scientists with the ability to be able to work in the laboratory but at the same time have an extension to a field experiment or have ideas from a field experiment and then driving what’s done in the laboratories there are very few places where that is currently possible. So it has created rather a bottleneck at the moment. Whether there will be a reverse trend in the universities, I don’t know”.

“Young scientists used to come through the PBI. We’ve had a bit of a problem you know with young scientists, well I’m 60 now a lot of my colleagues are 50 and there was a gap for those 20 years after privatization of the PBI. Now we’re getting younger people in the bottom again. I think it’s beginning to go back again.”
Currently, doctoral training is performed primarily within the institutes (Rothamsted Research and John Innes Centre). Doctoral training programs are funded for the most part by BBSRC. There is also the Laws Trust at Rothamsted (which is the charitable side of Rothamsted) that funds a couple of studentships each year and they will link in with either the University of Reading or the University of Nottingham. HGCA provides some money for training of PhD students and then industry can apply for projects to the BBSRC and get what is called a case studentship.

The industry is worried about too little scientists trained and concerns have been expressed during the interviews:

“They are worried. I mean when your average application list for a job is two you could either say it’s very efficient or you could say it’s scarily scary because if you have only two applicants possibly for a year and actually there may be even more jobs if suddenly two of the breeding institutes and companies want a particular person then there’s not enough to go around. So at the moment those PhD students know that they are being trained in a very unusual way.”

One way how the private sector is coping with lack of junior scientists is to provide an in-house training.

One scientist indicated that lack of people interested in crop science is a global issue rather than an issue associated with the structure of the UK wheat industry. Part of the problem is erosion of agricultural colleges all over the world. But the biggest issue is that agriculture and agricultural R&D has not been priority for governments until recently and this has created a perception that other sectors such as medicine or banking industry are better in terms of potential incomes. A quote from one interviewee supports this:

“In my own group I’ve had some really outstanding students come through my group but they’ve all switched… they went back into medicine. You know that’s just the way, there is more funding, better career prospects but I think with the food security issue becoming higher on the political agenda I think now people are beginning to see it is really important to have crop scientists. We lost basically a generation of agronomists, physiologists, that kind of thing as well. And it wasn’t just wheat, it’s a whole group… Erosion of agricultural colleges is part of it but also I think it’s because people are more interested in the medical side rather than the agricultural side. I think at one point agriculture wasn’t a
key priority for governments and the thinking was that if we had food shortage then we could buy our way out of it. Well, that argument’s gone.”

As was revealed during the interviews it is important for the success of the crop research industry that universities train scientists and breeders – something that the UK had lost with privatization because the universities and research institutes were deprived of their land and were cut off of field work. As was indicated by private breeder, maintaining pre-breeding activities in the public domain is essential to ensure that scientists have hands-on experience and that universities can train people that can easily take the work from the lab to the field. Breeding programs at universities serve important research and training roles and should not be viewed as commercial enterprise that does not deserve the right for existence if it is not profitable:

“When I look at universities in the US and in Canada, you’ve got breeders working in the university and they have four roles. They have an administrative role because everybody in a university does, they have a research role, a training role, and they run a breeding program. Now why do they run a breeding program? Well partly because they’re interested in it but partly because it helps them do their research work and train people. So it’s there for that reason but there’s been a driver to make that piece self financing because it’s totally applied research and therefore not seen as high value, right? So therefore, the hardest thing is sort of field technician if you’re a university breeder. So you want someone to fund that that’s a way of getting partnerships in with private. But then you say: why do it? There is a value in having a breeding program in a university that is helping you do your research or helping you do your teaching but does it have to produce new varieties? It might do but does it have to? What you really want is to be producing material from what might better be called a pre-breeding program. It’s still breeding right and then releasing it out. That would be to me a much better partnership type situation. So rather than compete with each other [public with private], link the chain up. You could have a consortia of breeders, private breeders who work with each of the individual university pre-breeding programs that help take whatever is produced and use it but also guide the research areas that were required and therefore what was done in that pre-breeding program and also the people being trained would be focused on the areas which are going to be important in the future because you know we [private industry] are looking forward and saying what we need. They are
being trained for what is needed in the future. So there would be a way of doing that rather than compete because if you look what happened in the US, say soybean breeding disappeared in universities because they couldn’t compete in delivering varieties but in a way they should never have been trying to compete in delivering varieties. They should have been doing their research with breeding programs associated to deliver something but not necessarily financial income which supported pre-breeding program. I mean I’ve talked to some of the university professors in the US who’ve got wheat breeding programs now and they don’t feel secure because they’re not earning enough income to cover the program and there’s one retiring fairly soon and they’re not convinced that they’ll replace him, which is ridiculous really but it’s because they are looking at it and saying that breeding program doesn’t cover its cost. Well it shouldn’t be seen as a breeding program expected to do that. That’s what we [private companies] have to worry about. We have to cover our costs and make money but it’s not what I see as a university breeding objective”.

5.2 Lack of strategic vision

With the recent research initiatives, the government has tried to build the UK wheat research system on the requirement that most of the research that is being undertaken is of value to the industry. Yet, many interviewees indicated that there is still a great deal of tension between basic research and strategic research. As was indicated by many, the system has not reached a proper balance as to how much funding needs to be spent on commodities and crops and how much funding needs to be spent on basic science:

“I think it is still a challenge for the UK to get the balance right between the money that it invests in research that’s targeted at particular areas and the money that’s designed for pure blue sky research and I’m not sure they’ve ever got that balance right.

...You know one of the issues with the BBSRC, they may like, may want to have more sort of applied projects with outcomes that really have impact but, through their committee system, they don’t really have a lot of control over that because they bring in a bunch of people from the committee sit in the room and make a decision on what’s
going to be funded... There’s always a strong pull towards high quality science that’s going to generate nature science papers. So, the plant of interest is usually arabidopsis and the top scientists in John Innes Centre you know the main magnets for that type of funding. Crop scientists rarely reach those heights but I think we pack more of a punch when it comes to value and impact rather than impact factor. Yeah we have impact in getting practical outcomes whereas arabidopsis has high impact factor in journals.”

5.3 Lack of long-run commitment

While various initiatives have restored the link between the commercial breeding sector and science, lack of long-term commitment has been mentioned by all interviewees as the largest drawback of the current crop research system in the UK. At the moment, the government makes a commitment for at most five years but given the long-term nature of crop research and breeding 5-year funding is viewed as a very short-term strategy. Because of such short-term vision, for certain projects scientists are only able to get to a certain point and the results of that work tend to get wasted because they just go on the shelf.

“We also find it very difficult to get follow-up funding. So if you develop a fine mapping population like we have done recently, so that took five years to develop this specialized mapping population, it would be great if we could implement them. We can’t now get follow-on funding to actually utilize those populations to find map and position in clone. So we have a great set of tools but no follow-on funding to take them forward. So I think if I was going to sort of improve things then certainly from my perspective it would be to look at the possibility for a longer term framework of funding. I think it would address these more practical aspects of pre-breeding and taking technology into the field.”
5.4 Lack of applied research in strategic areas

Since the privatization of the PBI, the UK system has not yet fully recovered from the breakdown in the research-breeding pipeline. As was indicated by most of the interviewees, the current system cannot be characterized as the one that is very successful in going from a nice gene concept, from the fundamental end and bringing that through. Even though the government initiatives have improved the communication between the basic and applied science there is still a gap between what the public researchers do and the most applied research. The most applied research is what private breeders routinely do which is “growing segregating populations in a field, having someone go out and select them and develop a new strain, a new variety that is improved and better than the previous one”. The private sector is primarily involved in tweaking the plant components and breeding systems. The universities and research institutes, on the other hand, do scientific work going down the most incredible details; they get down to a single gene to understand what one gene does and hope to extrapolate up from there. Applied research is about taking something that looks interesting and works at the fundamental level and transferring this knowledge into the germplasm of a specific crop. Bridging this gap between fundamental research and the most applied research can take another 10-15 years and lack of funding to bridge that gap is one of the weakest points in the UK system as identified by the respondents:

“There are still gaps in the research. One which we’ve identified at the moment is in applied research. The government in the UK seems very reluctant in really funding applied research in plant science or at least they think they are but actually it’s not really happening. What I mean by that is when something comes out of the fundamental end and it becomes less attractive from a researcher’s perspective, fewer publications possible, then it’s expected you [private breeder] just take it on and there’s very little funding in that area in a way and you know that’s just the way it is...”

Lack of applied research was associated with the current reward structure:

“The issue with strategy for funding plant science research is it tends to be not put together into one strategy. It’s always ‘we’re solving that problem, now we’ll solve that problem’ … It’s actually trying to get above it and say “Look we’ve got to sort of set it out properly” and one of the issues you’ve got within research, which is driven a lot of this lack of applied research, is the way that the academics are actually rewarded. So for example, the one thing that used to happen when PBI
was a lot old was that the people working on the applied area seemed to be rewarded either by promotion or more money as well as the ones doing the fundamental research because it’s all in one organization but that’s changed and now unless you’re pumping out papers pretty regularly and if you get an occasional one in *Nature* then you’re not going to become a professor and you’re not going to get merit promotions to the higher levels of the organization. So, therefore it’s a disincentive to actually do anything on the applied side right and that is a major stumbling block. You know whenever I’m in a meeting within funding bodies I mention this and they all say “Yes, it is a stumbling block” and they never manage to find a solution. So it’s difficult really and I can’t say I’ve got a solution for it other than if you had sufficient numbers of people who worked in the applied area who could assess whether someone is doing a good job or not. The same way that people do assessments of people who put loads of papers out and decide whether those papers are valuable use for delivering anything or not. So I don’t think it’s the impossible thing to solve but then you’ve got to figure out how you might solve that. Well BBSRC is not full of applied researchers, it can only assess itself on the way it knows how and we’re lacking that bit now. So, we’ve got maybe more of a problem in the UK than some of the other European countries but it is a driver in the wrong direction unfortunately.”

Lack of public funding for applied research creates another issue for the wheat research/breeding industry in the UK. During the past 30 years plant breeding has become international. Globally, governments have come to realize that tackling food security challenge is no longer a national objective but rather the whole international community has to work together towards this goal. In recent years we have seen increased international collaboration and International Research Initiative for Wheat Improvement is just one example of an attempt of different countries to combine their efforts in wheat research and breeding. As was mentioned during one of the interviews, the UK funding model puts the UK breeders at a disadvantage because without an applied research funding body they are left out of international collaboration:

The other things that happen in terms of research funding as well is that there are bilateral agreements between countries and the BBSRC gets involved in quite a lot of those and in the UK, of course, we suffer because we don’t actually have an applied research funding body. So, I
know from the German side of things, Germany, for example, gets involved a lot with France and Spain and Canada working a lot on what you might call more applied research but they can’t get involved with the UK because there isn’t a funding body to actually get involved with. The interactions on an international basis are also very important and offer opportunities for governments to sort of leverage their funding better by using experts in other countries as well and bringing the links together which is only good.”

Another challenge that arises from lack of applied research in the public domain is that some important areas of applied research are ignored by the private sector. Wheat is the crop that does not generate as much revenue as maize or canola. Therefore, private breeding companies will give priority to those traits that will help them sell their varieties to farmers. Yield is at the top of the list and as a result breeding efforts in the UK has been directed primarily towards yield with grain quality being ignored:

“Big gap in research is quality. …There is a danger that we’re going to make big piles of grain that no one wants to eat; also we are going to miss big opportunities because the first grade molecular marker for wheat was a quality marker because, you know, you could screen early on in the generations before you could ever do quality tests and make some great predictions. So again I feel it’s a missed opportunity. …I think the quality is ignored as a trait because it is very intangible. So quality to North African markets is totally different to what the crop quality is for UK, even between France and the UK you know, it’s very silent in that way and also the traits are low heritability traits so they are difficult to work with and the other thing is it’s kind of, often with government, with money that originated from government it relates back to a policy initiative and it’s always going to come back to the sustainability of farming and the environment, the rural landscape, things like that and it’s not so obvious how quality fits into that although it does.”

“When you’re talking about global food security, when you’re talking about UK commercial stuff it’s always the case with funding agencies that they think someone else should be doing quality. It is a hole in UK research at the moment.”
“A lot [when choosing the direction of public research programs] depends on the interest of breeders and the breeders at the moment are not very supportive of research on quality. There are various reasons for that … obviously their main target is yield and a major component of that is crop protection. Either intrinsic yield or controlling pest and pathogens and they’re much more supportive of our [public research] programs in those areas”.

5.5 Insufficient investment in bioinformatics

With all of the advancement in genomics technologies and the cost of generating sequences going down it is important to enhance capacity to analyze data. Bioinformaticians to analyze genomics data are in fairly short supply and this has been acknowledged by all of the interviewees. A quote from one wheat scientist supports this:

“At the moment I see that the area of genome sequencing and sequence provision is very well funded. The actual full analysis of that data I don’t think is properly funded. I think the data will be generated and it will just be sitting in a warehouse and probably it will never be unraveled properly, fully analyzed or even published. The phenotypic pillar of LOLA, for example, has really been squeezed tight. It has really been just bare bones funding and to do it [the analysis] properly we need four times the amount of money or more. So at the moment funding for good field phenotyping is missing without a doubt.”
6. Lessons for Canada

The privatization of wheat research in the UK provides many important lessons for Canada or any other country that is contemplating the privatization of wheat breeding. The outcomes, policy changes, and responses that have occurred in twenty-five years that have elapsed since the sale of PBI provide tangible examples of the outcomes from privatization of wheat research, yielding lessons about measures that should be pursued and those actions that should not be repeated.

**LESSON 1:**

*If Canada intends to create a private industry with the scale and scope to be internationally competitive either IPRs must be much stronger than the UK 52.5% farm saved seed royalty, or additional funding mechanisms are required.*

The UK royalty collection system operates efficiently with a coverage of more than 90% of the acres. Despite this extensive coverage, the pricing effect of the discounted farm saved seed royalty has kept royalty rates at low levels. The result is a very modest royalty stream generating $28million in royalties, of which approximately $9 million dollars get reinvested in breeding activities, or about 55 cents per tonne of wheat produced. If Canada wants to create an intensive breeding system, this will require either property rights with even higher legislated royalty rates on farm saved seed or a producer levy system, or both.

**LESSON 2:**

*Modestly sized private breeding industries require significant applied research support in order to be internationally competitive.*

The UK experience clearly illustrates that breeding firms with limited budgets cannot afford to make significant investments in plant science or crop science. While the UK government may have anticipated long-term public research savings, the recent level of reinvestment, suggests that private breeding activities continue to require significant long term public support.
LESSON 3:

If commercial breeding is removed from the public sector mechanisms that maintain the linkages between applied public researchers and downstream breeding activities must be put into place.

There was general view among our interviewees that the UK lost 10 to 15 years of wheat improvement by severing public researcher incentives to do applied crop science research:

“…from the heady days of PBI if you like, at that time Britain was leading, a world rank leader in research and development within crops and that has declined. I view Britain as very much just another country that would be involved; so when you go to the EU, when you’re in a room with sixteen other institutes from across Europe, the context of Britain as the world leader is not there at all. So you might be thinking who in this room invests the most but I suppose it must be the Germany and French. Britain is very much outside; in some ways almost outside Europe in a sense, isolating itself. So I think Britain’s standing as a research power, super power has diminished as a result of privatization and research capacity that we’ve lost.”

The UK learned the hard way that without incentives to do otherwise, competitively based science funding will attract public researchers toward activities with academic impact and away from applied research. If there are not clear incentives to work together the link between producers, private breeders, and public scientists weaken. As these linkages become weaker the knowledge flow is impeded, further reducing the effectiveness of the upstream public science research. The UK discovered programs that encouraged collaborative research and were quite effective in bringing public scientists and breeders together. Although it is also worth noting that some tension has continued to persist as the timeframe and reference points for public scientists and breeders differ.

LESSON 4:

Government mandated five-year funding blocks are a major impediment to long-term strategic research investments. Despite 25 years of post privatization experience, the UK continues to lack a long term strategic plan for wheat innovation.

In the last 13 years, the UK government introduced many new research funding initiatives, (WGIN, LOLA, WISP, STB, etc.) each designed to foster wheat innovation. While these programs have brought much needed research resources to the sector, public researchers and the
private breeders lamented the lack of a strategic plan and the inability to develop and fund long-term projects beyond the five-year commitment periods.

LESSON 5:

*Mechanisms to enhance knowledge sharing are important. Therefore, transition planning should develop policies to reduce knowledge and research fragmentation.*

The sale of Cambridge PBI and subsequent downsizing resulted in four distinct breeding programs. Plant breeders’ rights, mechanisms to share germplasm, genomics research, and other upstream knowledge provide efficient knowledge sharing and keeps breeders on a level playing field.

LESSON 6:

*The UK appears to have developed an efficient and effective two tier system of variety registration and recommended variety lists, which might have potential for application in Canada.*

Varieties must conform to well-defined standards to achieve National Variety Listing. To be selected for Recommended Variety List, nationally listed varieties are subject to additional testing organized by the Home Grown Cereal Authority and must meet stronger requirements. The UK national variety trials are done with the participation of private breeders, which lowers costs and enhances knowledge sharing.

LESSON 7:

*Privatization of UK wheat breeding has made it more difficult to train crop scientists and crop breeders.*

The UK experience clearly illustrates that breeding and crop science are not a dichotomy. Good crop scientists need to understand breeding and breeders need to understand crop science. Although some training opportunities now exist, the removal of commercial breeding activities from public institutions has made it more difficult to fund and train students with the knowledge of breeding crop science. University breeding programs should not be viewed as commercial enterprise that does not deserve the right for existence if it does not generate profit; breeding programs at universities should be viewed as hubs of training good crop scientists and breeders. Therefore, for training purposes, public scientists should not be alienated from the field with at
least pre-breeding activities, if not the release of commercial varieties, residing with the public sector.
References


APPENDIX

A. PROFESSIONAL BACKGROUND
1. Can you describe your professional background including the number of years you have been a wheat scientist/breeder?
2. What type of wheat research does your organization/unit do? What type of wheat are you working on?
3. What is your role within your organization?

B. RESEARCH FUNDING
1. How is your research program currently funded?
2. Has funding changed much over time? If yes, please describe the nature of changes and how these changes have affected your research program.
3. Has the amount of private investment in wheat research/breeding increased in the last 10-15 years? If yes, what has made wheat more attractive to private investment?
4. Is there enough funding in the British wheat industry to remain internationally competitive?
5. If you could change the structure of research funding in the UK, what changes would you make and why?
6. In terms of the whole country and in your opinion: Is the amount of wheat research/breeding investment adequate? Are there research needs that are not being met? If yes, what are those needs? Who should undertake these activities – the public or private sector?

C. INTELLECTUAL PROPERTY MANAGEMENT
1. How important is protection of intellectual property (IP) for your program/organization?
2. How do you protect the IP if at all?
3. Has IP changed the way you communicate with other researchers in the private/public sector?
4. Is managing IP a large cost for your organization?
5. How has IP affected your freedom to operate (FTO)? Is patent thicket a problem for your program? What strategies do you employ to maintain FTO?
6. Do you see seed saving by farmers as a potential hindrance to wheat breeding research? If yes, what practices do you employ to limit seed saving by farmers?
D. **PUBLIC-PRIVATE AND PUBLIC-PUBLIC PARTNERSHIPS**

1. Do you have any formal partnership agreements with private companies/public institutions?
2. Has collaboration with the private/public sector increased in the last 10 years? If yes, what are the reasons? How has increased collaboration affected your research/breeding program?
3. Do private firms/public institutions or farm organizations have any formal input into the content of your research program?
4. In what areas do you collaborate with the private/public sector? How is IP managed in public-private collaborative agreements?
5. In your opinion, what are the benefits and what are the costs of public-private collaborations.
6. Speaking of public-private partnerships, what do you see as major challenges to successful collaboration?

E. **THE UK WHEAT INNOVATION SYSTEM**

1. Can you describe the current wheat research/breeding system? Who are the major actors and what is an approximate share of the private sector in total wheat research/breeding?
2. Can you describe major changes that have occurred in the wheat research industry in the last 10-20 years? How has the role of the public sector changed? Has there been any change in the composition of public and private R&D investment?
3. How has your research program been affected by all of the changes that you just described?
4. Given the current system, do you think the UK will remain internationally competitive? If yes, in your opinion what are the strengths of the current system? If not, what challenges does the current system face?
5. What do you think the system will look like 10 years from now? Do you see public-private partnerships playing a larger role in the future?
6. If you were to reform the UK wheat research system what changes would you make and why?