PUBLIC, PRODUCER, PRIVATE PARTNERSHIPS AND EPR SYSTEMS IN AUSTRALIAN WHEAT BREEDING

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ABSTRACT

Australia has a crop research system with higher research intensity than exists internationally. Motivated to improve R&D policy in Canada, this dissertation focuses on the Australian End Point Royalty (EPR) system for wheat and addresses four principal questions: (1) How was the Australian system created and how does it work? (2) How do public, producer and private ownership of breeding programs affect the pricing of varieties? (3) How do EPR rates affect wheat variety adoption? (4) Finally, how would uniform EPR rates, similar to those used in France, affect variety selection, total production and revenue if used in the Australian market? In addressing the first question I use existing literature and interviews with prominent personnel in the Australian wheat breeding system, including management of InterGrain, AGT, DAFWA, GRDC and others. Interviews were conducted during field study in Australia in 2011. In addressing the second question I employ a horizontal location model to analyze three game theoretic scenarios of a two firm oligopoly market with private, public and producer owned-breeding companies. The results show public and producer ownership of one of the wheat breeding programs reduces price level relative to private only ownership. I derive a novel result showing that when competing with private firms who must price above marginal cost, the public firm should also price above marginal cost in order to maximize total industry surplus. In addressing the third question I develop and estimate an econometric wheat variety adoption model for Western Australia. I find EPR rates have a negative inelastic, statistically significant impact on the adoption of varieties.

Finally, in addressing the last question, I use the econometric model to simulate the adoption of Australian wheat varieties, given a counterfactual of revenue neutral uniform EPR rates. The uniform EPR rates speed up both the adoption and dis-adoption of varieties, thereby increasing weighted average yield and total production. The value of the increase in value of production exceeds the revenue for breeders under varying EPR rates, suggesting uniform EPR system may be an attractive alternative to varying EPR rates.

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LIST of ABBREVIATIONS

ACPFG	Australian Centre for Plant Functional Genomics
AGP	Australian General Purpose (Wheat)
AGT	Australian Grain Technology
AH	Australian Hard (Wheat)
APW	Australian Premium White (Wheat)
AUD	Australian Dollar
ASFT	Australian Soft (Wheat)
ASW	Australian Standard White (Wheat)
ASWN	Australian Standard White Noodle (Wheat)
AWB	Australian Wheat Board
AWCPA	Australian Winter Cereals Pre-Breeding Alliance
CAC Act	the Commonwealth Authorities and Companies Act
CVO	Contribution Volontaire Obligatoire
CWRS	Canadian Western Red Spring (Wheat)
CSIRO	the Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia
DPI	Department of Primary Industry
DPIVic	Department of Primary Industry Victoria
DWL	Dead Weight Losses
EGA	Enterprise Grains Australia
EPR	End Point Royalties
GBA	Grain Biotech Australia
GDP	Gross Domestic Product
GNIS	*Groupement National Interprofessionnel des Semences et des plants'*
GRDC	Grain Research and Development Corporation
GVP	Gross Value of Production
HRZ Wheats	High Rainfall Zone Whaets
ICA	The International Cooperative Alliance
IPR	Intellectual Property Rights
MC	Marginal Cost
MPBCRC	Molecular Plant Breeding Cooperative Research Centre
MR	Marginal Revenue
NSWDPI	New South Wales Department of Primary Industry
NVT	New Variety Trail
OLS	Ordinary Least Squares
PBR Act	Plant Breeders Rights Act
PIERD Act	Primary Industry and Energy Research and Development Act
QDPI	Queensland Department of Primary Industry
R&D	Research and Development
RDC	Research and Development Corporation
SARDI	The South Australian Research and Development Institute
SICASOV	*Société Coopérative d'Intérêt Collectif Agricole anonyme des Sélectionneurs Obtenteurs*

UPOV	Union for the Protection of New Varieties of Plants
VIF	Variance Inflation Factors
WA	Western Australia
WADA	Western Australia Department of Agriculture
WGRF	Western Grain Research Foundation
WLS	Weighted Least Square
YR	Yield Ratio

Chapter 1

INTRODUCTION

1.1 Background and Rationale

Agricultural innovation is one of the greatest achievements of mankind. Agricultural research and development delivers a broad range of benefits, including productivity growth, improved environmental outcomes, and other social benefits (Productivity Commission 2011; Huffman and Just 1999). Future population and income growth, as well as climate change, creates the imperative for an effective global crop innovation system (Alston et al. 2010). An effective crop innovation system increases the ability of the agricultural industry to compete in the global marketplace (Gray 2011). Access to new varieties is also important for sustained economic viability of farmers.

1.2 Goal and Objectives

The goal of this study is to explore the Australian system of delivering agricultural research development and extension by studying key aspects in more detail. The Australian system of delivering research and extension has achieved higher research intensity than exists internationally. While the system is complex, various aspects are interesting and create a somewhat novel economical phenomenon. The Australian wheat breeding industry currently consists of four main breeding companies whose creation involved vertical separation and horizontal integration. The incentives to create institutions (i.e. producers and government's funded and managed GRDC) to coordinate nationally (i.e. GRDC role, pre breeding alliance) and to enter into corporate partnerships with different organizational forms (i.e. state governments, GRDC, private companies) were shaped by policy. The use of end point royalties, spanning nearly 20 years, provides some empirical evidence to how this collection mechanism affects adoption and how the system evolves over time.

This study answers general questions related to the effectiveness of the Australian wheat breeding system. First, it explores how private, public, and producer ownership structures influence the incentives for royalty rate setting within a mixed duopoly. Secondly, it empirically estimates the impact of EPR rates on adoption. Finally, it compares varying and uniform EPR pricing impacts on adoption and welfare.

Objectives

The objectives of this study are as follows:

- Provide a description of Australian and French systems for funding agricultural R&D.
- Develop a theoretical framework to examine pricing under different ownership structures. Specifically, public, producer, and private ownership will each influence price setting, the adoption of new varieties, and the welfare impacts of crop breeding within a mixed oligopoly.
- Empirically explore the EPRs pricing and variety adoption in Western Australia and the impact of that pricing on the welfare of all the groups directly and indirectly involved in the sector.
- Analyze variety adoption and the impacts on welfare under a uniform EPR pricing as a counterfactual to Australian outcomes.

1.3 Issues with Research and Development

As explained by Fulton and Gray (2007), when there is a lack of strong Intellectual Property Rights (IPR), the private sector has limited incentives to invest in research because research output is a public good. Public goods are non-excludable and non-rival, where *excludability* denotes the ability to prevent others from using a good and *rivalry* refers to the extent that the use of a good by one person prevents its use by someone else. The non-excludable benefits from research and development, gained without fee in a market transaction, denoted as "spillovers", create a market failure as a consequence of improperly aligning the social marginal value of a good and the marginal cost of producing that good (Alston 2002). Governments have used numerous policies to address that market failure, including the public provision of R&D,

the subsidization of private R&D, the creation of non-market institutions to provide R&D, and the strengthening of IPRs (Gray 2011; Fulton and Gray 2007).

Private agricultural research investment is much greater where the IPRs and other forms of excludability have enabled capturing benefits from research. Significant private research investments are done in hybrid and patentable transgenic crops such as corn, canola and soybeans. Fuglie et al. (2011) found, "In 2010 global private-sector investments in R&D related to agricultural inputs reached $11.03 billion USD, an increase from $5.58 billion in 1994" (p. VI), noting considerable differences among countries and across technologies. Alston et al. (2010) observed that much of the private research and development was undertaken in developed economies. Fuglie et al. (2011) also found that private investment was concentrated in seven input categories (crop seed and biotechnology, crop protection chemicals, synthetic fertilizers, farm machinery, animal breeding and genetics, animal health, and animal nutrition) with crop expenditures being the leading category.

While the IPR mechanism has been successful in increasing private investment in agricultural R&D, it has also created numerous problems related to the toll good nature of protected knowledge[1]. Fulton (1997) and Lesser (1998) argued that an industry using a toll good as a main input is expected to end up as a substantially concentrated market as the industries using knowledge in their production processes realize economies of size and scale. In turn, market power has an impact on the welfare of producers and consumers (Loury 1979). Since toll goods are non-rival and have to be purchased or created just once, companies using a toll good as an input have high fixed costs and relatively low marginal costs. The average cost strictly decreases with output increase and is always greater than the marginal cost. These industry cost structure conditions create an environment for a natural monopoly (Lesser 1998).

Fuglie et al. (2011) found the concentration predicted by Fulton (1997) and Lesser (1998) has become an issue in US agricultural research, indicating,

[1] The knowledge protected by Intellectual Property Rights is both non-rival and excludable, which are the characteristics of a toll good (Fulton and Gray 2007).

the largest four to eight firms in each sector accounted for about three-fourths of the R&D in that sector, with larger firms spending more than smaller firms on R&D as a percentage of product sales … In most of the agricultural input industries, market concentration increased during 1994-2009, with the highest levels observed in the animal breeding and crop seed sectors and the largest increase observed in the crop seed sector (Fuglie et al. 2011, p. VI).

Research spillovers (related to non-excludability) cause a market failure and the optimal level of research is not delivered. The underinvestment in agricultural research is confirmed by the existing empirical evidence, which suggests the returns to agricultural R&D, though variable, are high on average. For example, Alston et al. (2000) conducted a meta-analysis of public agricultural research and indicated an overall mean internal rate of return to agricultural R&D (Table 12, p.55) as 81.3 percent per annum and a median of internal rate of return equal to 44.3 percent. Alston et al. also found the majority of internal rates of return to agricultural research reported in the literature fall in range between 20 and 60 percent per annum. These rates of return, which are likely considerably higher than discount rates, suggest both public and private sectors significantly underinvest in agricultural research. The recent estimates by Alston et al. (2010) found the United States national benefit/cost ratio for state funded research to be on average 32.1/1 and for USDA agricultural R&D to be 17.5/1. The results reported above uniformly suggest the presence of persistent underinvestment in research.

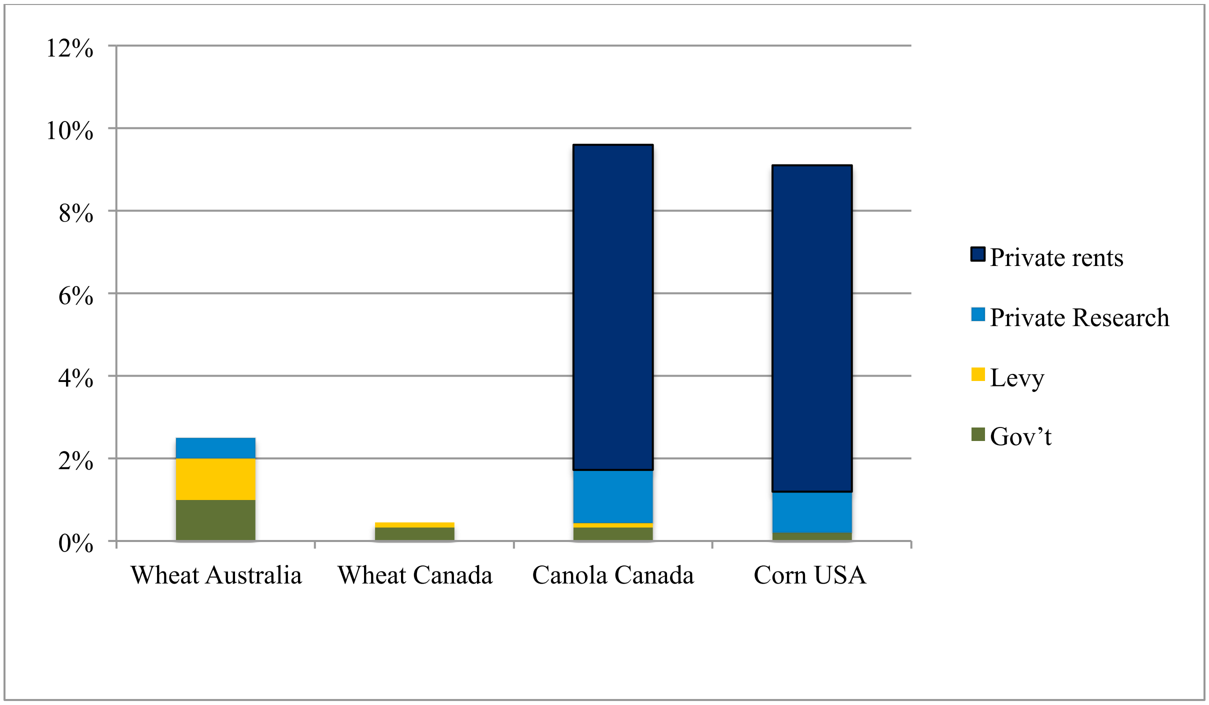

Figure 1.1 Comparison of Research Intensity Across Funding Regimes

Source: Gray and Bolek 2012

Figure 1.1 created by Gray and Bolek (2012) offers a comparison of research intensity for different crops and systems; wheat, being of particular interest in this study, is one of them. The seed royalties on wheat in Canada are limited and private research investments are small. Over the past decade the producer controlled Western Grain Research Foundation (WGRF), which generates revenue from a $0.30 per ton refundable check-off, has invested about five million dollars (CDN) in wheat research per year.[2] The Canadian Government delivers the majority of funding for wheat research. The overall investment in wheat research is approximately $20 million per year. With $4 billion in wheat sales, that investment denotes a research intensity of 0.5 % of gross sales, which is much lower than the 2% intensity in Canola and Australian wheat (Alston et al. 2012; Gray and Bolek 2012).

[2] In 2012 the Government of Canada introduced regulations that allow farmers to continue voluntary contributions to WGRF, Canadian International Grains Institute (CIGI) and the Canadian Malting Barley Technical Centre (WGRF 2012).

Research in the Canadian Canola sector is an example of an outstanding success. Decades of public research created a stage for the development of substantial investment by the private sector. Private investment was stimulated by biotechnology tools including hybridization of the crop in the last decade, but also increased ability to protect intellectual property through patents. Moreover, the support of producer and public agronomic research, access to a flow of publically developed germplasm and, the departure of the public sector from variety development activities created positive environment for private investment (Gray and Bolek 2010, 2012). Gray and Bolek (2012) estimated Canola seed and royalty revenue to be $720 million, of which $65 million was invested in Canola research. In addition to a large amount of private investments, the public sector and producer check–offs continue to fund Canola research, bringing total research intensity to slightly less than 2% of industry sales. US corn, which has strong IPRs, is also dominated by private research and has research intensity over 1 % of gross industry sales. Although research intensity in canola and corn is high, it comes at a higher seed cost to the producers. With hybrid seed and patent protected GM technologies, farmers pay upwards of 10% of gross revenue for seed each year (Gray and Bolek 2012).

Australia, compared to other countries, invests an exceptional amount in wheat breeding. Breeders collect the End Point Royalties (EPRs) from varieties protected by the Plant Breeders Rights Act, paid by producers at first point of sale. The total research intensity is over 2%. The Australian wheat research system is characterized by higher research intensity than wheat research in Canada, at a much lower cost for producers than Canola. Although wheat and canola in Canada and wheat in Australia have comparable size, research intensity and cost to producers among those systems differs significantly.

1.4 Australian Example of Funding System for Wheat Breeding

As mentioned above, Australia has a system for funding R&D that enables much higher research (wheat breeding) intensity than exists internationally. Given its high research intensity, features of the Australian agricultural research funding system could be a model for countries such as Canada and the US who are dealing with underinvestment in agricultural R&D.

The Grain Research and Development Corporation (GRDC), established in 1990, has played a pivotal role in the system of funding agricultural research in Australia. The GRDC is funded by a growers' levy of 1% of value of production paid on 25 crops, matched by government on a dollar for dollar basis up to 0.5 % of GVP. From 1990 until 2007, the GRDC supported public wheat breeding programs.

The GRDC then led a further transformation of the wheat innovation system by undertaking a tender process to look for partnerships. The introduction of the Plant Breeders Rights Act (PBR Act) in 1994 empowered "plant breeders to charge an End Point Royalty (EPR) on the first sale of harvested material derived from varieties protected by plant breeders' rights" (Kingwell and Watson 1998, p.324). These strong property rights created the potential for a revenue stream from the sale of new wheat varieties. Roughly sixteen years after their introduction, EPRs have increased to the point of being able to fund breeding programs. With this revenue stream in mind, the GRDC partnered with public and private shareholders in commercially based wheat-breeding corporations.

With increasing EPR rates and the process of adoption of newer varieties over time, the Australian wheat breeding companies have the potential to generate a significant profit from the sale of their varieties. This raises the question of how these firms with public and GRDC shareholders are going to behave in the future; as a private company or public entity. Most company representatives interviewed in 2011 anticipated these firms will act as commercial entities and maximize the return to shareholders (Budd 2011). This suggests there is strong pressure to continue to increase royalty rates and potentially create an outcome similar to hybrid crops. However, opinions were not all consistent and some suggested these firms perhaps could act in grower interests and reflect only the cost of breeding in future EPR rates (Walmsley 2011).

France also has an interesting alternative of the EPR system where a uniform EPR is charged on all bread wheat varieties. The uniform EPR rate is negotiated between the national farmer organization and the seed industry (Gray 2011). This EPR structure not only simplifies royalty collection but also changes the dynamics of EPRs over time. Because the uniform EPR applies to all varieties, it can be introduced at a commercially viable level and the negotiated rate setting prevents excess rent extraction by the breeding firms. Given the attractive features of

France's EPR system, the adoption and welfare implications of uniform EPR rates warrant further study.

Despite some early signs of success and some potential shortcomings, neither the Australian nor French model has yet to receive a lot of formal analysis in the economic literature.[3] Regardless of nearly twenty years of history of EPRs in Australia, there has been little study of how EPRs have affected producer adoption of varieties or how rate setting has been affected by the privatization of breeding programs. Further analysis of the rate setting incentives of the private, public and producer shareholders may provide some insight into future behaviour of these mixed enterprises.

1.5 Contribution to the Literature

This study contributes to existing economic literature in a number of ways and constitutes useful analysis for policymakers in Canada as UPOV 91 is implemented. First of all, this dissertation provides an extensive description of the Australian system for funding wheat breeding and analyzes numerous aspects of the funding system. The description of the Australian system was based on existing literature and knowledge obtained during personal interviews with 12 people involved in the Australian wheat research funding system and its creation. Interviews with prominent figures within the Australian wheat breeding system were completed during a field study involving a 4-month visit to Australia in 2011. Interviewed experts included management of GRDC, InterGrain, AGT, DAFWA, and others as listed in the references. Interviewing people who have been involved in the system for a period of time provided additional context of each step of creation of the system as well as an integrated and comprehensive understanding of the whole wheat breeding system, enriched by the experiences and vantage points of key individuals within the system.

The theoretical modeling of the pricing behaviour of companies with different ownership structures within a mixed oligopoly produces a novel result which shows maximum social welfare is obtained when the public company is pricing above marginal cost and below the price charged by its private competitor.

[3] Ross Kingwell and Robert Lindner have done some economic analysis of the Australian system.

In the empirical chapter the estimated adoption model for wheat varieties in Western Australia fits well. Notably, I was able to obtain statistically significant results describing the negative impact of EPR rates on variety adoption.

Finally, I conclude the study by comparing the welfare implications of varying and uniform EPR rates, both of which are options as Canada implements UPOV 91. While economic theory suggests ambiguous impacts, the empirical simulation using the estimated model shows that change from a varying EPR system to a uniform EPR system increases welfare by tangibly accelerating the adoption of superior varieties.

1.6 Dissertation Outline

The analysis required to meet the dissertation goals and objectives is developed in six chapters. Chapter One provides the introduction to the dissertation, background for agricultural research importance and underinvestment, End Point Royalty systems and welfare implications, as well as research goals and objectives.

Chapter Two focuses on the Australian wheat breeding system and the reform of that system, the creation of the GRDC, and the publicly, producer, and privately owned firms for the purpose of plant breeding and commercialization of new varieties.

Chapter Three uses a theoretical model to analyze the pricing behaviour of breeding companies given different ownership structures such as private company, producer owned company and public company. Each of the above mentioned company structures compete in an oligopoly market with a private company. To model an oligopoly market under three scenarios and examine impacts of ownership on EPR rates setting, the horizontal differentiation model with specifications taken from the Malla and Gray (2005) paper is used.

Chapter Four chooses the most appropriate adoption model to predict wheat varieties adoption patterns and estimates an impact of EPR rates on adoption. Adoption and EPR data from Western Australia is used to estimate the chosen model. A theoretical model along with econometrically estimated parameters is then reported and tested.

Chapter Five uses the estimation results from Chapter Four to analyze the impact of uniform EPR rates on variety adoption and created welfare. The existing EPR structure is compared to a counterfactual system where revenue neutral uniform EPR rates are employed. Finally, Chapter Six provides a summary and conclusions of the dissertation as well as an outline of further research needs.

Chapter 2

AUSTRALIAN WHEAT BREEDING SYSTEM and ITS REFORM

2.1 Introduction

Australia has a very successful wheat breeding and commercialization system. The research intensity in the Australian wheat breeding system exceeds the research intensity that exists in other countries. Historically, Australian crop research was publicly funded. Over the last 25 years, the Australian research system has undergone a very significant transformation. Currently, there are four major wheat-breeding companies in Australia, three of which are producer, public, and private partnerships.

The objective of this chapter is to describe the Australian wheat breeding system and its reform with the creation of the RDCs model and establishment of 3 wheat-breeding companies. The description of the Australian system and its reform provided in this chapter is based on knowledge obtained from existing literature and 12 interviews with prominent figures within the Australian wheat breeding system conducted during 4 months of field study in Australia in 2011.

2.2. Development of Research System and Creation of RDC Model

Although historically, most agricultural R&D in Australia was publicly funded (Kingwell 2005; Brennan and Mullen 1998), since 1900, there have been rural R&D levy regimes introduced by producers. Most of those regimes (for example, Pastoral Research Trust and Wheat Growers' Soil Fertility Research Fund) were funded by voluntary producers' levies and were having numerous 'free-rider' problems.

In 1957, the first of 14 statutory advisory committees (including representatives from the Department of Primary Industry, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and producer groups) was established. The 14 committees administered the funds collected from an obligatory producer levy for promotion and research that was established in 1936 and since 1945 was matched by the Government. The Minister made funding decisions using recommendations from the advisory committees. This model persisted until 1985 (Productivity Commission 2011).

In the early 1980s, the Commonwealth Government was generally dissatisfied with the way the agriculture research system was performing. The main issue was allocating funds to the projects without considering expected rates of return. Research tended to be fragmented, small, and a number of policy problems came up (Watson 2011). The Government saw a need of focusing research for pivotal areas (Productivity Commission 2011).

The Rural Industries Research Act of 1985 restructured the governance of funding for industry specific R&D and was a precursor for the existing RDC model. Under the 1985 Act, research councils replaced individual research committees, and began to manage the trust funds. More uniform funding arrangements were created across the industry. The councils were dispersing funds among research providers in the name of commodity groups and were accountable to the Australian Government for the expenditures of government funds (Productivity Commission 2011).

Creation of research councils did not resolve the concerns regarding administration of rural R&D funds. Still there were issues regarding poor co-ordination and communication among councils. Clarity of decision making processes continued to be a problem. The Government thought the councils had to be oriented to meet industry needs and develop varieties that would succeed in the commercial market (Kerin and Cook 1989).

The Primary Industries and Energy Research and Development Act 1989 (PIERD Act) addressed those issues by establishing the existing statutory model for the RDCs. The RDCs replaced industry research councils. The funding arrangements remained the same. The creation of a corporation model intended to improve the efficiency of spending R&D funds. The RDCs have flexibility in the way each operates and spends funds. Each of the RDCs focus on the needs of its industry, invest in R&D to develop the industry, and contribute to profitability and competitiveness of the industry (Brennan and Mullen 1998). The RDCs operate as a broker in research and have a large amount of funding to dispose, therefore integrate the research system in the industry. The RDC model intends to address broader, along with industry-specific rural research needs. The broader research need is one reason for government contribution (Productivity Commission 2011). The model was intended to improve matching market needs. Unlike the previous model, which relied on researchers to set the agenda, the RDC model has solid connections with producers and the important contribution that producers have to the cost of the R&D restricts the wasting of funds (Kerin 2010). The Productivity Commission's reviews (2011) of the RDC system found high rates of adoption of R&D and connections across businesses.

The RDC responsible for wheat, a subject of interest in this study, is the Grain Research and Development Corporation (GRDC). As defined in the GRDC annual report 2008-2009, "The GRDC is a statutory corporation, operating as a research investment body on behalf of Australian grain growers and the Australian Government. As well as its responsibilities under the PIERD Act, the corporation has accountability and reporting obligations set out in the Commonwealth Authorities and Companies Act 1997 (CAC Act) and in the Commonwealth Authorities and Companies"(GRDC 2009, p.11).

The skill based GRDC's Board is accountable to Australia's grain growers through the industry's organization, and to Parliament through the Minister for Agriculture, Fisheries and Forestry (GRDC 2009). The GRDC manages the grower levies, collected from 25 crops[4]. For grain the levy rate is 1% net farm gate value matched by government up to 0.5 % of GVP. The GRDC is responsible for setting the agenda in many critical areas of applied breeding and breeding infrastructure. The GRDC does not conduct research; it co-ordinates a research investment plan and invests in research and development for the stakeholders (GRDC 2009).

2.3 Establishment of Wheat Breeding Companies.

As of 1990, there was a number of small scale breeding programs in Australia; several state departments and universities had their own program. The GRDC funded breeding projects operated at each of these public institutions and owned the resulting varieties. The system was characterized by a large number of small-scale programs that led to a question of overall

[4] Wheat, barley, oats, sorghum, maize, triticale, millets/panicums, cereal rye, canary seed, lupins, field peas, chickpeas, faba beans, vetch, peanuts, mung beans, navy beans, pigeon peas, cowpeas, lentils, canola, sunflower, soybean, safflower, linseed (GRDC 2009).

efficiency. The GRDC believed there was no need for nine wheat-breeding programs in Australia for a 25 million ton crop market (Budd 2011). They believed a small number of bigger programs run at world leading standards using the value capture mechanism – the End Point Royalties (EPRs), would allow for breeding programs to become profitable in time (Budd 2011). The GRDC also believed those programs would be large enough and have the resources necessary to be able to adopt technologies coming from multinational companies (such as Monsanto). Consequently, by the end of the1990s, the GRDC led a transformation of the wheat innovation system.

GRDC was funding a review of the nation's wheat breeding programs and estimation of its forthcoming needs. The initial attempt at developing a more streamlined breeding program in Australia was an unincorporated joint venture with the state governments of Western Australia, New South Wales, and Queensland. Enterprise Grains Australia (EGA) previously known as the National Wheat Breeding Program was created (Farmweekly 2013). Member States soon became uncomfortable with funding out of State research, leading to the demise of EGA. The GRDC then initiated a tendering process looking for three new wheat-breeding partnerships.

Several state governments also undertook efforts to reform wheat-breeding programs. State governments were looking for the more efficient ways to do wheat breeding, trying different approaches, selling wheat breeding programs, licencing them and establishing partnerships. State governments all over Australia had gone down different paths. For instance, Victoria decided to exit wheat breeding, shut down its wheat breeding program and licensed out its germplasm. The South Australia government decided to set up a company, AGT. The Department of Agriculture and Food Western Australia (DAFWA) was part of EGA initially, but in 2004, DAFWA (at that time known as Western Australia Department of Agriculture WADA) decided EGA was right for the eastern states but didn't provide much benefit for Western Australia. Under previous arrangements, DAFWA remained a committed partner in the EGA until mid-2005 (Farmweekly 2013) then opted out and wanted to set up a fully commercial unit that had autonomy and was completely driven from a commercial basis, away from the political scene of state government. As such, they set up InterGrain (Loughman 2011; Metcalfe 2011).

GRDC tendering process resulted in the creation of 3 partnerships with state governments and universities (later to be joined by private companies) for wheat breeding. The established companies include; the Australian Grain Technology Pty Ltd, launched in 2002, HRZ Wheat Pty Ltd, launched in 2003, and InterGrain Pty Ltd, launched in 2007. There is also a fourth, wholly privately owned breeding company named LongReach Pty. Ltd. One of the key reasons for corporatizing wheat breeding in Australia was to set it up for other players, such as multinational companies, to invest and bring their technology in (Budd 2011). The GRDC's role in wheat breeding was largely pulled back to the shareholder level in these self-funded entities. The GRDC played a vital role in attracting multinational companies to enter into wheat breeding in Australia by being seen as independent of government and also by giving credibility to a more commercial approach. Although it is possible to use licenses and arrangements, the shareholder relationships tend to be much deeper, much stronger and technology is more readily available with integration.

2.3.1 Australian Grain Technologies Pty Ltd

The largest breeding company in Australia, the Australian Grain Technology Pty Ltd, (AGT) based in Adelaide, was formed in 2002. The original shareholders of the AGT were the GRDC, the South Australian Research and Development Institute and, the University of Adelaide. The AGT also licensed the mainstream of the Victorian Department of Primary Industries' (DPI Vic) wheat-breeding germplasm. The AGT expanded and became an international breeding company. In 2005, there was a merger between AGT and SunPrime Seeds Pty Ltd. With the merger AGT became Australia's only completely joint wheat breeding and commercialization company. Moreover, the AGT Pty Ltd and the Council of Grain Grower Organizations established a partnership in 2007 and Vilmorin & Cie, an exclusively owned subsidiary of Limagrain Holdings, acquired a 25 per cent share in AGT in 2008 (AGT 2012).

AGT was the first venture with multiple predominately public, shareholders. In the AGT model, the existing participants in the breeding process and owners of the IP did not roll their variety IP into the company at the company start. As a result, the company did not have a revenue base on which to build its income. AGT had to establish its own variety profile, release its own varieties, build their uptake in the industry and capture value from that. Consequently, AGT had a series of transitional funding arrangements. Given they were no longer in the public domain, they recognized that investors needed to make equity contributions in order to get the company to a point where it was financially viable.

2.3.2 The InterGrain Pty Ltd

InterGrain Pty Ltd (InterGrain) is the second largest crop breeding company and the largest wheat breeding company in Australia with approximately 80% of the market in Western Australia. InterGrain was established in October 2007, with the Government of Western Australia initially holding 70% of the shares and the GRDC initially holding 30% of the shares. InterGrain's wheat-breeding programs aim to develop for the states of Western Australia, South Australia, Victoria and New South Wales. A substantial amount of the drive for changes, and creation of InterGrain came from the GRDC (Loughman 2011). DAFWA had range of R&D activities that were either directly or indirectly supporting the objectives of the wheat-breeding program. In 2007, the GRDC's contribution of about 20% of the DAFWA programs ran out and GRDC chose not to extend that support. At the same time, there was a nation-wide movement to improve the wheat breeding system. DAFWA considered options such as to set up a company, InterGrain, to sell their IP, or to license IP. A final decision to set up a company was made in 2007 (Loughman 2011). From the start, there was an acknowledgement that the company would need to attract third party investment (Meyer 2011). On 24 August 2010, Monsanto became a minority shareholder in InterGrain, getting 19.9% of the shares in return for a cash injection and InterGrain's access to Monsanto's proprietary market assisted breeding technologies. Later on, Monsanto purchased additional shares. Currently, InterGrain has three major shareholders: Western Australia Government (48.7%), GRDC (25.3%) and Monsanto (26%) (InterGrain 2012).

When InterGrain was established, DAFWA's assets that directly supported the wheat-breeding program and related IP were rolled into InterGrain. The ownership of the IP, GRDC's equity, and the Western Australia Agriculture Authority through the Department of Agriculture in Western Australia's equity, was transferred to the company, such that the company then owned the PBR rights on existing varieties and all the background and germplasm (Loughman 2011). The other elements of R&D in relation to grain quality characteristics, adaptation to environment, or biotics distinct from the core breeding program, have been maintained by DAFWA. DAFWA still has R&D activities in the area of pre-breeding. These pre-breeding activities, previously oriented to deliver to the DAFWA's breeding program, continue to be supported but are no longer delivered exclusively to the Western Australian program (Loughman 2011). In September 2009, InterGrain's management interviewed and officially selected the wheat breeding staff from DAFWA. The preliminary focal point of InterGrain was wheat, but later was extended also to barley. In 2011, InterGrain had 5 wheat breeders and 2 barley breeders (Walmsley 2011).

InterGrain is currently completely reliant on EPRs as the company does not receive any GRDC levies or direct Government support. InterGrain operates as a corporate company. The management of the company is done under a five-year strategic plan. InterGrain's management reports to all of its shareholders. InterGrain's shareholders contribute to the company at various levels. Regardless of the ownership of the company, InterGrain continues to have business relationships with GRDC and DAFWA.

Currently DAFWA is the largest shareholder of InterGrain with 48.7% of the shares. DAFWA provided the company with financial input at the time of establishment. DAFWA also contributes to InterGrain through business relationships. There is a commercial lease agreement for several key-breeding assets and InterGrain buys numerous services from DAFWA. For instance, a large portion of InterGrain's grain quality work is contracted to DAFWA and then delivered under a service position, by commercial arrangements.

The GRDC is a shareholder in InterGrain with 25.3% of the shares and continues to contribute to InterGrain through the support of pre-breeding and a range of supportive agronomic research. In making its upstream and downstream investments, the GRDC consults with InterGrain and with the Wheat Breeders Alliance, made up of all the wheat-breeding companies (Walmsley 2011).

Monsanto currently owns 26% of InterGrain shares. There is a separate collaboration agreement between InterGrain and Monsanto. The collaboration with Monsanto is based on germplasm exchange, technology exchange including the use and development of market assisted breeding, and access to biotech traits in the longer term (InterGrain 2012).

InterGrain has also established an alliance with Nuseed, a subsidiary of Nufarm. The alliance offers growers quick access to new varieties and has created an on-line trading site (www.seedpool.com.au) to assist trading between farmers. As a consequence of the alliance, InterGrain has also gained an access to the wheat-breeding germplasm previously owned by Victorian DPI (InterGrain 2012).

A strategic objective of InterGrain is to maintain market position, as there are new entrants in the market. In an attempt to expand markets and reduce risk, InterGrain is targeting variety development across southern Australia. In 2011, the goal of InterGrain was to achieve a 30-40% market share in Victoria and New South Wales within five to ten years. This is part of a risk management strategy recognising that if there were a bad season in one side of the country, there may not be a bad season on the other side of the country (Walmsley 2011).

2.3.3 HRZ Wheats Pty Ltd

The smallest among major wheat breeding companies in Australia is HRZ Wheats Pty Ltd. (HRZ Wheats). HRZ Wheats breeds milling-quality wheats for the high-rainfall zone (HRZ) of Australia (HRZ Wheats 2013). HRZ Wheats was established in November 2003 by CSIRO, New Zealand's Institute for Crop and Food Research (the predecessor to the New Zealand Institute for Plant and Food Research), and the Western Australia-based Export Grains Centre Ltd. At the beginning of 2008, the Export Grains Centre reassigned its shares in HRZ Wheats to GRDC. In June 2009 and in September 2011 Landmark Operations Ltd and Dow AgroSciences respectively bought shares in the HRZ Wheats (CSIRO 2014). By the end of 2013 Dow AgroSciences bought GRDC's and New Zealand's Institute for Crop and Food Research's interests in HRZ Wheats. On July 1, 2013, the HRZ Wheats switched its name to Advantage Wheats Pty Ltd and implemented a new logo (HRZ Wheats 2013).

2.3.4 LongReach Plant Breeders Pty Ltd

Among the four major wheat-breeding companies in Australia, three are public, producer, private partnerships described above. The fourth is LongReach Plant Breeders Pty Ltd. LongReach Plant Breeders was established in 2002 as a joint venture between Syngenta Seeds Pty Ltd (currently Syngenta Australia Pty Ltd) and AWB-Landmark. Syngenta bought the

Landmark shares in 2006 and in late 2007; Syngenta sold a bulk of shares in the LongReach to Pacific Seeds Pty Ltd (LongReach 2012).

2.4 Plant Breeders Rights Act

An important factor that enabled privatization of wheat breeding programs in Australia was the introduction of the Plant Breeder's Rights Act in 1994. IPRs for plant varieties in Australia were initially created by the Plant Variety Rights Act of 1987 (Kingwell 2005; Kingwell and Watson 1998). The Plant Variety Rights Act 1987 had a minor impact on breeding because it did not apply IPRs to farm saved seed. Farmers in Australia were sowing mainly farm saved seed, therefore industry had fairly limited returns. The breeders' rights were extended to harvested material by the Plant Breeder's Rights Act 1994. It allowed plant breeders to obtain revenue by imposing royalties known as End Point Royalties. Producers who are authorised to grow a variety contractually agree to pay an End Point Royalty on harvested material. If producers fail to pay the EPR, the legislation enables breeders to enforce their rights on harvested material.

2.5 The End Point Royalties (EPRs)

Kingwell and Watson (1998) defined EPRs as "a levy imposed on the first sale of harvested material derived from varieties protected by plant breeders' rights." (p. 324). The EPRs are attached to new varieties and are the way to compensate breeders for innovation and effort. The EPRs comprise a breeder royalty and, in most cases, a collection fee and a management fee to commercialise and market the variety. The largest portion of the total royalty owed by the grower is the breeder royalty (InterGrain 2012). The EPRs are a value capture mechanism that attracted private companies by giving them an incentive to invest in wheat breeding in Australia. The EPR is owed on each year's production for the variety protected by the PBR Act during its commercial life for no longer than 20 years. The EPR is deducted at the first point of sale or commercial use. As stated on InterGrain's webpage, "Growers must pay the royalty on every tonne of harvested grain whether sold or retained on farm, except for seed saved for sowing purposes. The EPR applies to each successive crop produced from the grower saved seed."(InterGrain 2012a, p.1). The PBR Act prohibits farm-to-farm selling seed; however, breeding companies that own a variety have a right to give permission to trade a particular variety from farm to farm. InterGrain gave permission for farm-to-farm selling seeds for all varieties in Western Australia as a way to increase adoption rates (McGrath 2011). The existing Australian method does not rely on extension of the Plant Breeder's Right, per se, to harvested output, but relies on the use of contracts and also centralized collection points to secure payment of the EPR on the harvested material (McGrath 2011; Walmsley 2011).

In Australia, the use of EPRs is growing for wheat varieties. Since 1996, all newly released varieties have an EPR rate attached to it. The EPRs seem to be an efficient way of dealing with underinvestment in crop research. Plant breeders and seed industry claim the EPR regime is the most equitable means of guaranteeing sustained investment in plant breeding. Under the EPR system, breeders and growers share both the production risk and the rewards as farmers' payments are proportional to the success of the crop, not on the quantity of the seed they buy (Sanderson 2007). The EPR allows plant breeders to obtain a return on their investment and simultaneously diminish the cost of the seed for the producer. If a variety does not perform as well as it should, it will not be adopted and the breeding company will get a strong financial message. Finally, growers have quicker access to superior varieties as a result of efficient research and distribution methods (Sanderson 2007).

Sanderson (2007) also pointed out shortcomings of the EPR system. The introduction and use of EPRs was not without controversy. Some plant breeders and farmers complained about inefficient administration and collection of EPRs. Initially there was confusion surrounding administration of the EPR, as there were various collection methods and various contracts being used. The seed contracts could specify other terms and conditions such as price and quality limits that made EPR collection more complicated. Farmers were confused about their rights and obligations under various EPR contracts. Most of those issues have been addressed by appointing a single agent, Seedvise Pty Ltd. to make all negotiations and set contracts. Seedvise Pty Ltd is now representing almost 100% of the wheat industry (McGrath 2011).

Figure 2.1 represents the weighted average EPR rate of wheat variety adopted in Western Australia. As can be seen in Figure 2.1, the weighted average EPR rate has increased. Recently released varieties have EPR rates of about 3.5 dollars per tonne. Whether EPRs are going to increase further is an interesting question related to ownership of breeding companies and is discussed in Chapter 3 of this dissertation.

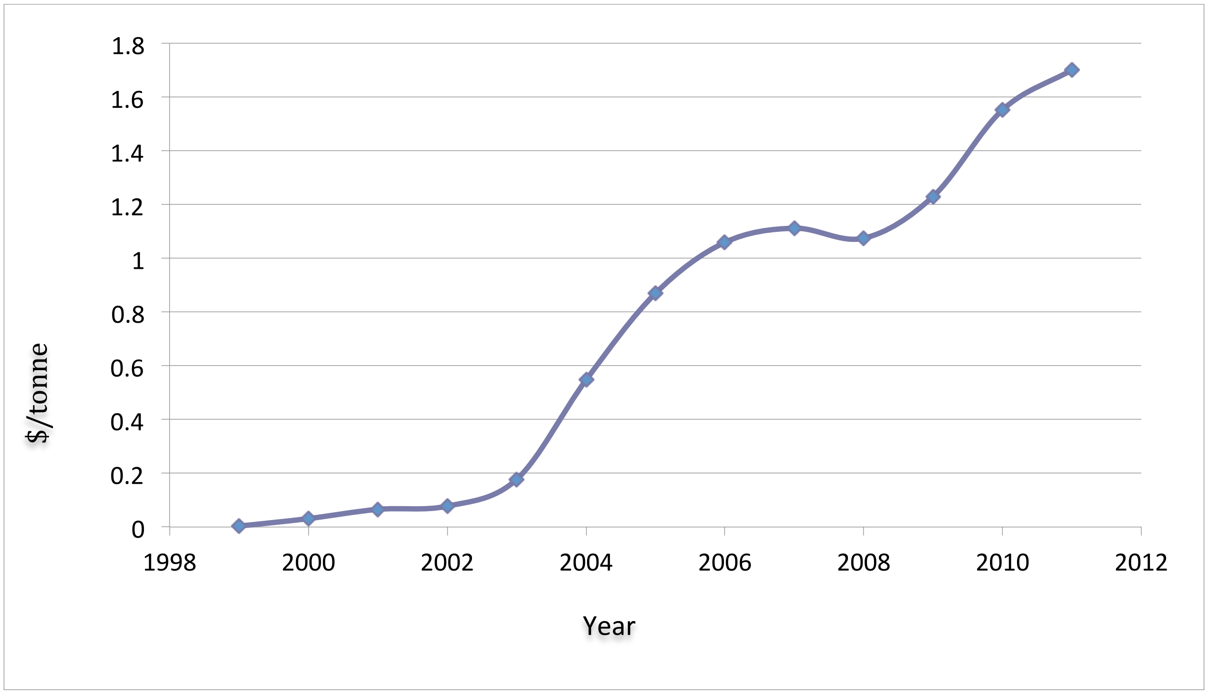

Figure 2.1 Weighted Average EPR Rate Attached to Wheat Varieties Adopted in State of Western Australia

Source: Author

EPR Collection

There are two main systems for collection of an EPR:

1. Some grain traders have the capacity to automatically deduct the money. In this situation, when the grain trader pays the grower they deduct the EPR and then forward the money to the breeding company. The grain traders generally pay EPR three times per year.
2. There are some grain traders who do not have the capacity to deduct money so breeding companies set up the system where those traders provide the breeding company/royalty managers with data on grower purchases and the breeding companies/royalty managers individually send out invoices to the growers directly. This method is also used for

growers who decide to use the grain on their own farm. In that situation, the grower provides data to the breeding company/royalty manager via the EPR Harvest Declaration Notices (Walmsley 2011; GRDC 2011).

In order to clarify the declaration process for growers, the key seed companies approved the Grower Harvest Declaration form. The Australian system of declaration is an honour system; the growers are required to declare their variety when they deliver it. As written on InterGrain's webpage; "It is an offence to 'mis-declare' varieties to avoid payment of EPRs at point of delivery or when completing a production declaration notice. A person who infringes PBR may face both civil and criminal proceedings for infringement" (InterGrain 2012a, p.1). This creates some issues around proceedings for infringement, especially when mis-declaration is not intentional. Often, it is not the grower who drives the truck to the receiving depot, but the trucker may not pay attention to the variety he is transporting.

The compliance rate for the EPRs is generally high, about 90% in Western Australia. Queensland is an exception with a low compliance rate of 40%. The possible reason for such a low compliance rate can be the farmer's argument about *double dipping*. Farmers believe they are paying twice, by paying levies and EPR. There is also higher use of feed grains in the region. Queensland is also a very small market and consequently, very few breeders directly breed for it, and therefore none put a concerted effort in educating growers about the importance and benefits of the EPRs.

2.6 The Current Role of the GRDC

Currently, the GRDC is investing in several types of grain research including pre-breeding, which given the long time lines and the lack of excludability, is not cost effective for breeding companies. The government has to make sure that it is doing pre-breeding work for traits that are going to be used, not for traits that are going to be of particular interest to scientists. The GRDC's role is to coordinate and ensure breeders are given access to the material used across growers (Budd 2011).

In 2010, the GRDC initiated the Australian Winter Cereals Pre-Breeding Alliance (AWCPA). The Alliance was created to encourage teamwork and cooperation among cereal pre-breeders. The objective of the Alliance is to take full advantage of the pre-breeding across the whole country and minimize the time between genetic enhancement and obtaining new, better-quality crop varieties. AWCPA was established by the steering committee on behalf of all main pre-breeding groups. The present structure of the Steering Committee embraces CSIRO, Molecular Plant Breeding Cooperative Research Centre (MPBCRC), University of Adelaide, The South Australian Research and Development Institute (SARDI), Australian Centre for Plant Functional Genomics (ACPFG), New South Wales Department of Primary Industry (NSWDPI), Queensland Department of Primary Industry (QDPI), Department of Primary Industry Victoria (DPIVic) and Department of Agriculture and Food Western Australia (DAFWA) (GRDC 2012, Meyer 2011).

2.7 Concluding Comments

Australia has a very successful wheat breeding and commercialization system, characterized by an intensity of research higher than what exists internationally. The country has a long history of levy-funded research. The GRDC, created in 1990, and funded by a growers' levy of 1% of value of production and matched by government on a dollar for dollar basis up to 0.5 per cent of GVP, has played a pivotal role in the development of the wheat breeding industry. In the late 1990's, the GRDC began to seek public and private partners for creation of wheat breeding corporations. As a result of these actions, Australia now has four major wheat breeding companies, three of which were established as public private producer partnerships (4P) with the GRDC. First and largest was the Australian Grain Technology, created in 2002, by GRDC, the SARDI and the University of Adelaide. In July 2008, Vilmorin & Cie purchased a 25 per cent share in AGT. The second largest crop breeding and largest wheat breading company is InterGrain, a joint venture between DAFWA and GRDC created in 2007. In 2010, Monsanto joined InterGrain. A third company, HRZ Wheat, was created in 2003 with CSIRO and New Zealand's Institute for Crop and Food Research, the WA-based Export Grains Centre Ltd and the GRDC. In 2011, Dow AgriSciences purchased shares in the HRZ Wheat. LongReach is the only completely private wheat breeding company in Australia.

With the establishment of commercial wheat breeding firms, the GRDC now predominantly invests in "R&D capacity building, pre-breeding research, developing new farm practices, breeding activities where there is still market failure, and other activities such as the NVT system." (GRDC 2011, p.4). GRDC is investing in projects of pre breeding activities to make sure the germplasm that industry needs is developed and available equally to all breeding companies.

The 1994 PBR Act, which enabled breeders to charge EPR, eventually created a revenue base required for the establishment of the 4P. While it took some time to develop an effective collection system and many more years for EPR rates of varieties competing with royalty free varieties, to reach compensatory levels, EPRs allowed plant breeders to get a return on their investment and simultaneously decrease the cost of the seed for the producer. In this market driven system, if a variety does not perform as well as it should, then that variety is not adopted, and the breeding company receives a strong financial message.

As varieties improve over time, the ability to charge higher EPR rates also increases. In hybrid crops, where breeding is dominated by the private sector, strong IPRs have resulted in seed costs approximately 10% of the gross value of the crop, and large rents have been generated for breeding firms. Current EPRs are approximately 1% the value of wheat production in Australia. At these rates, the 4P wheat-breeding firms are able to cover breeding expenses. A critical question is, what is the future of EPR rates in Australia? The public, producer and private identity of shareholders in the 4P wheat breeding firms bring up a question of how those wheat breeding companies are going to behave in a long run; whether they will be a profit maximizing company, social surplus maximizing or act as mixed ownership structured enterprises. This question is addressed in the Chapter 3 of this dissertation.

Chapter 3

FIRM OWNERSHIP and the INCENTIVES for NEW VARIETY PRICING

3.1 Chapter Objective

With a goal of gaining insight into the future of end-point royalty rates charged by the public, producer, private wheat partnerships in Australia, the objective of this chapter is to theoretically analyze the pricing incentives of companies with alternative ownership structures in a market for new wheat varieties. Recognizing new varieties as differentiated products and the limited competition in the market place, a horizontal product differentiation model with two firms is used for the analysis. The model provides some insights into how ownership influences the incentive for royalty setting in a mixed oligopoly.

3.1.1 Introduction

In December 2013, the Canadian federal government introduced Bill C18, which has been passed and make Canada compliant with the International Union for the Protection of New Varieties of Plants 1991 (UPOV 91). The Bill updates Canada's legislation from the former UPOV 78 framework. As Canada is implementing UPOV 91 and contemplates various ways to increase funding for agricultural R&D, especially wheat breeding, Australia presents a model that should be considered. With this in mind, this dissertation analyzes various aspects of the Australian system of wheat breeding with companies characterized by producer, private and public ownership.

Australia became compliant with UPOV 91 with the introduction of the Plant Breeders Rights Act in 1994, which enabled charging End Point Royalties.[5] The EPRs made possible self-

[5] Being compliant with UPOV 91 is not a base for charging EPR per se, charging EPR rates is based on contracts, but legislation makes those contracts enforceable.

funded wheat breeding partnerships. The establishment of wheat breeding partnerships was an attempt by the Grain Research and Development Corporation (GRDC), along with state and federal governments, to privatize wheat breeding in Australia. Currently, the Australian wheat breeding industry, as described in Chapter 2 of this dissertation, is made up of 4P wheat breeding firms with combination of private, producer and public shareholders. For example, the GRDC (25.3%), DAFWA (48.7%) and Monsanto (26%), own InterGrain, the largest wheat breeding company in Western Australia.

In order to assess the Australian wheat breeding system, it is important to understand how their EPR rates were functioning in the past, why this was the case and how they are likely to function in the future. After introduction of the Plant Breeder Rights Act in 1994 in Australia, wheat varieties with EPR rates attached to them had to compete with older, free wheat varieties present in the market. That impacted the level at which EPR rates were set, and made EPR rates lower than they would be otherwise. By 2011, the EPRs for wheat varieties had reached a level sufficient to fund the breeding activities of AGT and InterGrain (Walmsley 2011). The most recent wheat varieties in Australia have EPR rates of $3.50 per tonne. As these varieties become fully adopted, the EPRs will generate profit for breeding firms.

Corporate ownership of wheat varieties and strong Intellectual Property Rights (IPR) protection in the Australian wheat breeding system create some similarities with the hybrid seed market. As a result, hybrid seed market issues such as market concentration, resulting pricing behaviour and its consequences could also occur in the Australian wheat breeding market. In North American hybrid industries and biotech related crop research industries, there was an initial period of biotech firm proliferation followed by many mergers and acquisitions. By 2000, there were five sizable agri-chemical and biotechnology companies dominating the industry - Bayer, Dow, DuPont, Monsanto, and Syngenta (Wilson and Dahl 2010). Between the years 1994 to 2009, the increase in market concentration was predominantly evident in the global crop seed market with the four-firm concentration ratio, with the total output produced in an industry by the four largest firms rising from 21% in 1994 to 54% in 2009 (Fuglie et al. 2011, Table 1.7 p.15). In hybrid and biotech industries, seed costs have risen far quicker than overall farm input prices. Between the years 1999 to 2008, average prices paid for seeds in the US rose 146 percent

(Fuglie et al. 2011). Producers paid more than 10% of gross crop revenue for seed and seed firms earned a substantial gross margin on seed sales (Gray and Bolek 2012).

Fuglie and Toole (2014) emphasize that substantial industry concentration creates concerns about charging a price above marginal cost, but if having a market power to charge excessive prices increases incentives for private R&D, it could have a positive impact on welfare. By causing faster economic growth, high investments in R&D could counterbalance short-run welfare losses from the exercised market power. In hybrid seed markets reinvestment rates are typically low. In the case of corn and soybeans, research-intensive companies invest 10% of their gross returns in R&D (Gray and Bolek 2012). In another example, Canadian canola growers pay 15% of their gross income from canola for seed and the industry re-invests less than 10% of this revenue in research, producing a research intensity of 1.3% (Gray and Bolek 2012). These examples suggest that the welfare losses from charging excessive prices could be significant while the reinvestment rates are quite low, suggesting the Fuglie and Toole (2014) argument might not apply.

Public ownership and producer ownership of wheat breeding companies in an industry with strong IPRs changes the path of prices over time. If public or producer shareholders hold wider social objectives then theories that relate to the theory of "Second Best" may apply to that market situation. The theory of "Second Best" claims that in a situation where one of the Pareto optimum conditions cannot be fulfilled, the "Second Best" optimum outcome is accomplished only by departing from some other optimum conditions (Lipsey and Lancaster 1956). If distortion is not correctable, having two or more distortions might counteract the first distortion and lead to a more efficient outcome. Since there is market failure to deliver an optimal level of agricultural research, the introduction of strong IPRs is a necessary distortion created by policy. Given this distortion, other distortions such as regulating EPR rates with an objective of maximizing social surplus might increase overall efficiency.

Even though the Australian wheat-breeding firms have stated objectives to maximize profits, three of these firms have private, public and producer shareholders with uncertain influences of those shareholders on pricing behaviour of companies. Public and producer ownership could restrict the growth in EPR rates beyond self-funding levels. Arguably, it is still too early to tell how high future EPR rates will become as lower priced varieties disappear from the market. To help understand pricing done by those breeding companies, this chapter presents an analysis of the theoretical model of pricing behaviour with given ownership structures.

3.1.2 Chapter Outline

The remainder of Chapter 3 begins with a review of existing literature on concentration of ownership, consequences of dividing ownership and management with the agency theory approach, as well as efficiency and characteristics of each ownership form. In Section 3.3, the Malla and Gray (2005) horizontal differentiation model is introduced and adjusted to analyze the Australian wheat market situation within a static framework. Using this model, three scenarios of markets with two breeding companies are constructed and solved. The first scenario has two private companies compete with each other using a generic variety. The second scenario has two companies, one private and one public, competing with each other using a generic variety. Finally, the third scenario has two companies, one private and one producer owned, competing with each other using a generic variety. Section 3.4 discusses variety improvements impact on pricing and resulting total surplus differences in three considered scenarios. The chapter ends with concluding comments in Section 3.5.

3.2 Literature Review: Impacts of Ownership Structure on Company Objectives

The vast majority of research on different ownership structures is based on agency theory and deals with concentration of ownership. This study looks at the impact of the different identity of owners - private, public and producer - on the company's objectives and resulting pricing behaviour. The issues with ownership from agency theory based literature are also summarized in order to provide a broader picture of literature related to ownership.

The Berle and Means (1932) paper introduced consequences of the separation of ownership and management to the literature and it remained the focus of debate for more than 50 years. The Berle and Means paper shows that the diffusion of ownership structure modifies the link between ownership and control, undermines the role of profit maximization as a guide to resource allocation. Other research, by Fama and Jensen (1983), has used the concept of agency theory to study issues with separation of the ownership and control. Agency theory over the years has turned out to be the main theoretical reference in corporate governance research. Agency theory analyzes a relationship between principals (owners) and agents (managers) (Shleifer and Vishny 1997; Gedajlovic and Shapiro 1998; Thomsen and Pedersen 2000) and focuses on the problem of information asymmetry and its consequences (Short 1994). Thomsen and Pedersen (2000) stated, "…standard assumption is that owners want to maximize profits while managers have other interests, for example: minimizing efforts, empire building, high competition."(p. 690).

The identity of the owners has consequences for their objectives and the way they use their power to influence decisions made by a manager. The identity of the owners has impacts on company strategy, dividends, capital structure, growth rates, and profit goals (Thomsen and Pedersen 2000). Thomsen and Pedersen (2000), analyzed 435 of the leading European firms from different countries and industries controlling for country and industry effects, and suggested a hypothesis (following Short 1994 and Nickell et al. 1997) that the *identity* of a large owner can be important. Their results reflected the need to line up corporate strategy and the objective of the main owner. Reorganisation of ownership among the largest European firms in a way to create a better fit between ownership structure and company's strategy was found to generate gains. Thomsen and Pedersen (2000) found that large concentrations of government ownership led to significantly lower returns relative to other ownership identities. Thomsen and Pedersen (2000) also found the concentration of ownership affects the power of shareholders to affect managers' decisions; higher levels of ownership concentration results in greater power to influence managers. The economic performance is a nonlinear function of ownership concentration. The ownership concentration after some point has a negative consequence for performance. While Thomsen and Pedersen did not explicitly examine the firms' goals, they did conclude that, "…the observed differences in valuation and profitability appear to be inconsistent with overall shareholder value maximization. In contrast they are consistent with a priori hypothesis regarding the goals and preferences of alternative ownership categories." (p.703). The inference from their results is that ownership structure and governance play a role for corporate strategy. This literature suggests that the Australian firms could be influenced by their unique and concentrated ownership structure.

Private companies have stated objectives to maximize profit or long run value of the firm. In the literature, there are two major theories related to objectives with which firms are operating (Margolis and Walsh 2003). The first theory, “Value Maximization”, dominates economic literature and is two hundred years old. The second, “Stakeholder Theory”, became recently popular and is somewhat unfinished. Value maximization claims that all the decisions made by managers should aim to escalate the total long-run market value of the company. Total market value is the discounted amount of all financial claims on the firm[6] (Margolis and Walsh 2003).

Stakeholder theory, as an alternative, is based on the principle that the interests of all stakeholders in a firm should count when making decisions. Stakeholders embrace individuals or groups who are able to considerably affect the welfare of the firm, the financial claimants as well as employees, customers, communities, and governmental officials (Jensen 2002). Post et al. (2002) defined stakeholders by the role they play: "The stakeholders in a corporation are the individuals and constituencies that contribute, either voluntarily or involuntarily, to its wealth-creating capacity and activities, and are, therefore, its potential beneficiaries and/or risk bearers" (p. 19).

Both theories have its supporters. Misappropriation and misallocation of resources are the main grounds of the conflict between supporters of Value Maximization and Stakeholder Theory. Supporters of Value Maximization Theory claim that managers following Stakeholder Theory will misappropriate the company’s resources by driving them from their appropriate claims whether these are the firm's owners or employees and/or, misallocate resources by using them for purposes that they are poorly suited for. The company whose managers follow Stakeholder Theory run the risk of becoming non-competitive. It becomes difficult to evaluate managers’ decisions since there is no single objective upon which the decisions are made (Margolis and Walsh 2003).

Public companies, which are a product of public policy, often have the stated objective of maximizing the benefits for citizens where they operate in; in economic terms, it means to maximize social welfare. As discussed by Shirley and Walsh (2001) under the assumption that a

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[6] Jensen (2002) claims the maximizing long-term market value by individual firms is the best way to maximize social welfare.

public company operates efficiently, when there are significant sources of market failures, usually caused by monopoly or externalities (Shleifer 1998), managers of public companies are able to generate more efficient outcomes than managers in the private sector. Even operating as a monopoly, a public company that has an objective to maximize social welfare is able to correct prices and output to roughly the competitive equilibrium (Vickers and Yarrow 1989; Shleifer and Vishny 1994). Correspondingly, if industries with large cost externalities are dominated by public corporations, public managers are able to regulate prices to mirror the social cost of the product. Public companies may have also different social objectives than addressing market failure. Public companies may have an objective to increasing employment, regional development, or acceleration of technology transfer. Some researchers (Wintrobe 1987) claim that the benefits of social goals compensate the subsequent loss of efficiency. The empirical literature[7] has not really verified the claim that social benefits of public companies offset the economic costs (Shirley and Walsh 2001).

The property rights theory of the firm (Alchian 1961; Alchian and Kessel 1962; Alchian and Demsetz 1972; Shleifer 1998; Williamson 1969, 1970) states that private enterprise operates more efficiently and more profitably than public companies. Boardman and Vining (1989) following De Alessi (1980) summarized and discussed the essential difference between private and publicly owned companies. They stated the main difference is the fact that the ownership of public companies is non-transferable. This creates a lack of specialization in ownership of public companies and causes difficulty capitalizing on future ventures into contemporary prices. Additionally, decisions of managers in public companies may be less scrutinized by their "owners". The legitimacy of the property rights hypothesis that private companies perform more efficiently than public companies has been discussed by a number of authors. Frech (1980) noticed that a private manager, by increasing the wealth of the company, is able to increase his own wealth, but with the reduced price of "non-pecuniary benefits" the public managers' focus exclusively on substitution effects. The product of the income and substitution effects together is indeterminable. Grossman and Hart (1980) have shown that although property rights theory states that the takeover market eliminates managerial inefficiencies, in fact potential takeovers will not fully discourage non-profit maximizing behaviour by managers of private firms. They

[7] With the exception of a few case studies.

argue that since small shareholders will try to free ride and not tender their shares hoping to benefits from a raid, and consequently making the raid not profitable for raider, thereby deterring takeover. Empirical evidence provides weak support for the property rights based hypothesis.

Some scholars debated that competition in the markets is a more significant factor for company's efficient performance than public or private ownership (Vickers and Yarrow 1989). Others, such as Vining and Boardman (1990) disagree, and claim that ownership matters and there is evidence of superior performance of private corporations over publicly funded corporations. Empirical and theoretical research suggests that competition as well as ownership affects company performance and the effects of ownership contradict the influence of the market (Shirley and Walsh 2001).

The expansion of mixed, public, private enterprises, their significance and number create another problem. Mixed enterprises share some characteristics of both state owned enterprises and private corporations. For instance, the wheat-breeding firms in Australia claim a profit maximizing objective but have a majority of producer and public shareholders. The mixed enterprises do not have enough empirical studies done on their performance. The evidence collected by Boardman and Vining (1989) shows that "Mixed Enterprise" may act in a different way from either "Private Companies" or "State Owned Enterprise". This empirical study suggests that Mixed Enterprise perform better than State Owned Enterprise, however, worse than Private Companies. Boardman and Vining (1989) concluded that fractional privatization, when government keeps some percentage of equity, is not an efficient method of moving away from dependence on a public company.

Another important business form is the cooperative. The International Cooperative Alliance defines a cooperative as, "an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs" (ICA 2012, p.1) and as classified by Valentinov and Iliopoulos (2013), in the modern economic theory of the agricultural cooperative there are three views on what cooperatives are. These include, "(1) a form of vertical integration (or an agency) serving member farms, (2) a firm separate from member farms, or (3) a coalition (p.112)." Nourse (1922) and Emelianoff (1942) introduced the view of cooperatives as a vertical integration explaining that because of the "operation-at-cost principle", a cooperative does not earn profits or losses itself and, therefore, it is not a distinct company. The second approach introduced by Enke (1945) considers a cooperative to be a separate firm that optimizes some objective function. The numerous researchers contributing to the view proposed a different maxim, usually, referring to different definitions of members' welfare (e.g., Helmberger and Hoos 1962). The third approach introduced by Kaarlehto (1955) and Ohm (1956) considers a cooperative to be a coalition of members who have different goals and who remain members only if they think their goals are being satisfied. Therefore, cooperative's actions are the consequence of the bargaining process of participants and depend on their relative power (Valentinov and Iliopoulos 2013).

Among agriculture cooperatives the financial and organizational challenges are common (Fulton and Giannakas 2001; Fulton 1999). As the number of sectors in agriculture becomes concentrated and vertical integration and contracts are frequently used, cooperatives operating in that market structure have difficulties remaining competitive. Internal problems of cooperatives typically are related to the heterogeneity among members; greater property rights problems than in other forms of enterprise and weakening commitment of its members. This deteriorating commitment of members is one of the reasons for the decreasing market share and poor financial performance of numerous cooperatives (Fulton 1999). Cooperatives are not clearly inferior to Investor Owned Firms. However, constraints, such as constraints in raising capital, are frequently found in cooperatives while Investor Owned Firms typically do not have such problems (Evans and Meade 2006). Cooperatives when in the right circumstances can be more efficient compared to other business forms (Bontems and Fulton 2009).

In conclusion, the focus of the existing ownership literature is on agency theory and on the separation of ownership and management. This study, however, explores how different ownership could affect the pricing of the products of the company. As a first attempt to model the pricing behaviour in the context of a market for wheat varieties, we assume the behaviour of the firm will fully reflect the objectives of its shareholders; a privately owned company has the objective of maximizing profits; a producer owned breeding company has an objective to maximize welfare of its owners; and a public company has the objective to maximize social surplus. The agency cost of information asymmetry between shareholders and manager is assumed to be zero, and agency theory issues do not exist in modeled market.

The breeding companies that motivate this study were established for the specific purpose of creating new wheat varieties in the Australian market by investing in research and development. There are two innovation processes that can describe research and development (R&D), the vertical innovation process and horizontal innovation process (Sutton 1986; Mussa and Rosen 1978).

In the vertical innovation process, the new product is a higher quality than the existing product. If priced the same as an old product, a vertical innovation will replace the old product. In the horizontal innovation process a new product is different from an old product and if both are sold to heterogeneous buyers, if priced the same, both products will co-exist in the market place (Cozzi and Spinesi 2006). To model the effect of ownership structure on variety pricing and welfare this Chapter utilizes the horizontal theoretical model because typically, many wheat varieties tend to coexist in the marketplace at the same time.

3.3 The Variety Pricing Model

Wheat varieties must be *distinct* or *differentiated* from existing varieties because this is a condition for a variety to be registered. Farmers differ in their land characteristics and consequently, optimal characteristics of adopted varieties. As shown by examples such as Bayer Crop Science with Invigor™ or Monsanto with Roundup, varieties and chemicals are sequentially improved over time. All of those facts influenced a choice of the model for this study. The model developed in this section considers pricing and the market equilibrium for two horizontally differentiated varieties.

In this chapter, I consider three possible scenarios of the market, corresponding to different firm ownership to model the Australian wheat breeding market. As described in Chapter 2, the Australian wheat breeding market consists of four major wheat breeding companies, one completely private, LongReach, and three public producer private partnerships: AGT, InterGrain and HRZ Wheats. Therefore, scenarios of the wheat breeding market are created in the way that a private company is present in the market in all three scenarios and is competing against the second company, which in Scenario 1 is private, in Scenario 2 is public and in Scenario 3 is producer owned. Each company owns a horizontally differentiated product (wheat variety) that they sell to heterogeneous farmers.

The game theoretic model starts with deriving the demand and pricing for the crop varieties to ensure sub-game perfect market equilibrium. The specification of demand functions is the same as a Hotelling model by Malla and Gray (2005) where farmers differ by single land characteristic and are uniformly distributed along a continuous range of the land characteristic. As explained by Malla and Gray (2005),

> Land is heterogeneous with respect to the level of a land attribute ϕ_i (e.g., soil quality, weed infestation), which differentially affects the yield of each variety. For numerical convenience, the land attribute is assumed to be uniformly distributed, such that one unit of land is spread over one unit of ϕ_i. Farmers choose to purchase variety A from company A, variety B from company B, or the public generic variety G, for each type of land depending on which variety produces the highest net return. (Malla and Gray 2005, p. 424).

The reason why the Malla and Gray (2005) model, with a generic variety, has been chosen over the horizontal differentiation Hoteling model in range 0-1, is that in 0-1 range model, if there are two competing varieties in the market, total demand in this market is fixed unless prices are so high that varieties do not compete anymore, not something we observe in the market. The problem of having a fixed level of total demand is overcome by adding external margins. Therefore, this study is using the Malla and Gray (2005) model, presented in Figure 3.1, which allows variety A to compete with variety B on one margin and with a variety G on the second margin. Similarly, variety B competes with variety A on one margin and with a variety G on the other extensive margin.

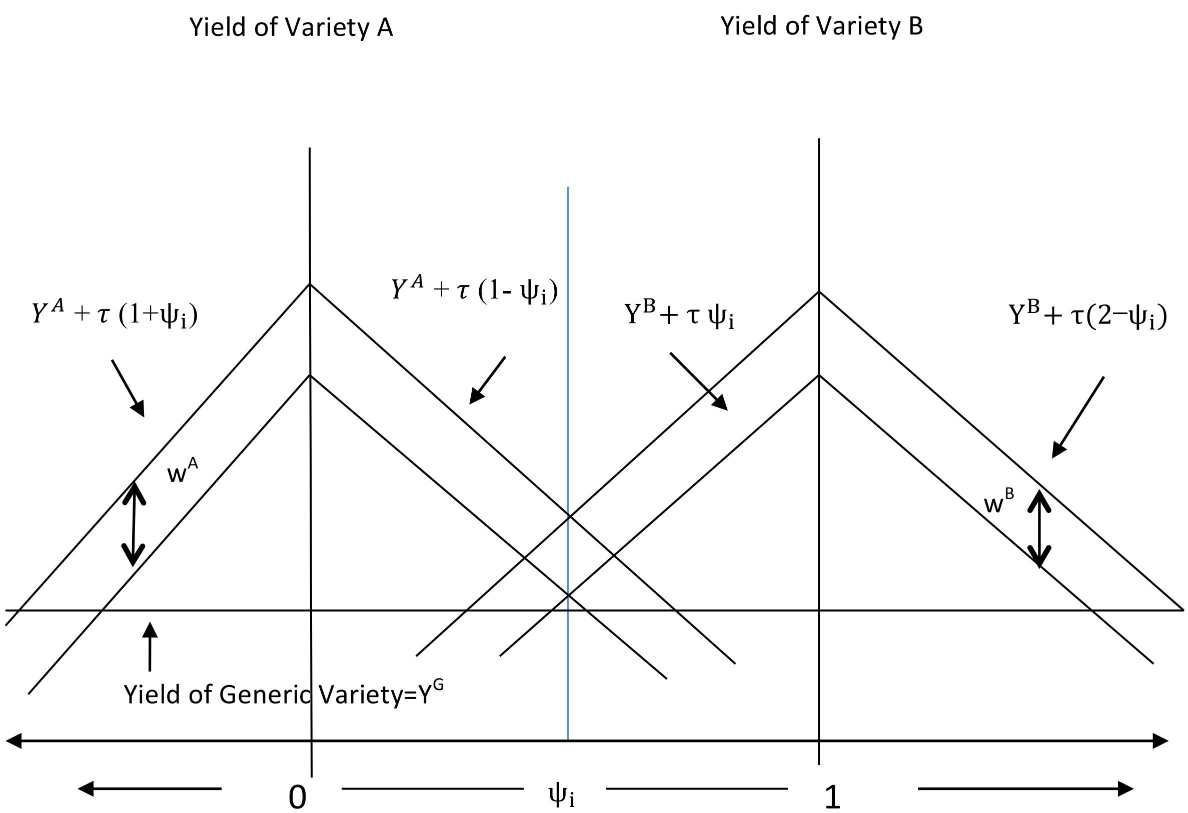

Figure 3.1 Horizontal Location Model with External Margins
Source: Author

It is assumed that the two differentiated varieties are best suited for a particular land characteristic, but are close enough in the product space to compete at positive prices. At the exterior margin, both varieties compete with a freely offered generic variety, which performs equally well for all land characteristics. In this demand space, I model a market with two breeding companies each selling a single differentiated variety.

As presented in Figure 3.1, variety *A* generates the highest yield at the location $\psi_i=0$ and yields $Y^A + \tau$ in that place. As one moves to the right or to the left of this location, the variety *A* generates a lower yield. Yield decreases linearly in a way presented by equations:

$$Y_i^A = Y^A + \tau\ (1-\psi_i) \text{ when } \psi_i \geq 0, \text{ and} \quad (3.1)$$

$$Y_i^A = Y^A + \tau\ (1+\psi_i) \text{ when } \psi_i \leq 0, \quad (3.2)$$

Variety *B* generates the highest yield at land characteristic $\psi_i = 1$ and yields

$$Y^B + \tau\, \psi_i \text{ when } \psi_i < 1, \text{ and} \tag{3.3}$$

$$Y^B + \tau(2 - \psi_i) \text{ when } \psi_i \geq 1. \tag{3.4}$$

The generic variety Y_i^G has constant for all the locations yield Y^G. With assumption that non-seed production costs are the same for all varieties and output price *P* is exogenous[8] and equal to 1, the net return to the acquisition of each variety *K* on all land types ψ_i is equal to:

$$Y_i^K(\psi_i) - w^K \textit{ for } K = A,B; \tag{3.5}$$

where:

w^K- is the price charged for the variety, w^K in this model is a seed royalty rate.[9]

Each firm competes for market share with the generic variety on one margin and the rival company on the second margin. For land characteristics in the region $\psi_i^{A,G}$, where $\psi_i < 0$, company A competes with the variety G. The value $\psi\hat{}_i^{A,G}$, which is the location where the farmer is indifferent between variety *A* and generic variety *G*, can be calculated by solving for the value of ψ_i for which the net profit from the purchase of variety *A*.

$$Y + \tau(1 + \psi\hat{}_i) - w^A \tag{3.6}$$

is equal to the net profits from the purchase of generic variety,

$$Y^G. \tag{3.7}$$

---

8 Canada and Australia each make up less than 4% of the world wheat market.

9 Since I am interested in ownership impact on pricing behaviour I did not model EPR but a simple per area royalties for transparency reasons. The objective functions of companies do not change as one change from seed royalty rates to EPR rates, and the calculations unnecessarily crowd a result without adding any new insights to ownership impact on pricing behaviour.

As a land has density of 1, the demanded quantity of variety *A*, is given by distance

$-\psi\hat{}_i^{A,G}$ and is equal to:

$$\frac{Y-Y^G+\tau-w^A}{\tau} = -\psi\hat{}_i^{A,G}. \tag{3.8}$$

On the second margin for in the location $\psi\hat{}_i$ in the 0 to 1 range, variety *A* will compete with variety *B*. The demanded for variety *A* is given by distance between 0 and $\psi\hat{}_i^{A,B}$, where $\psi\hat{}_i^{A,B}$, is the point at which both varieties give an equal net return.

$$\frac{\tau-w^A+w^B}{2\tau} = \psi\hat{}_i^{A,B} \tag{3.9}$$

The total demand for variety A is obtained by adding $-\psi\hat{}_i^{A,G}$ and $\psi\hat{}_i^{A,B}$

$$Q^A = \psi\hat{}_i^{A,B} + (-\psi\hat{}_i^{A,G}), \tag{3.10}$$

$$Q^A = \frac{2Y-2Y^G+3\tau-3w^A+w^B}{2\tau}. \tag{3.11}$$

Symmetrically, the demand for variety B, Q^B is obtained by adding $(\psi\hat{}_i^{B,G} - 1)$ and $(1-\psi\hat{}_i^{A,B})$

$$Q^B = \psi\hat{}_i^{B,G} - 1 + (1-\psi\hat{}_i^{A,B}), \tag{3.12}$$

$$Q^B = \frac{2Y-2Y^G+3\tau-3w^B+w^A}{2\tau}. \tag{3.13}$$

Using the obtained demand for both varieties, the prices of varieties *A* and *B* can be calculated. The marginal cost of production and marketing of the seed, *L*, is a constant and known to both breeding companies at this point, and equal to zero. Having derived demand curves for both varieties, we analyze pricing of those varieties depending on identity of the variety owner.

3.3.1 Scenario One: Case of Two Private Companies

If owner of variety *A*, and owner of variety *B* are private companies, both are setting their prices with a profit maximizing objective. Therefore, the objective function of firm *A* is

$$\text{Max } \pi^A = \left[Q^A\left({w_0}^A\right)\right] * {w_0}^A. \tag{3.14}$$

The objective function of firm B is

$$\text{Max } \pi^B = [Q^B({w_0}^B)] * {w_0}^B \tag{3.15}$$

Given there is a fixed cost for wheat breeding; each breeding firm is subject to a zero profit constraint.[10] When both firms are present this condition is assumed to be met, therefore, not modeled as a part of the royalty pricing equilibrium.

Profits maximizing objective functions for two private companies are illustrated in Figure 3.2.

[10] $R^K(w^K)>=R^F$, where R^F is minimum required revenue and optimal w^K would hold condition $w^K*>=w^F$.

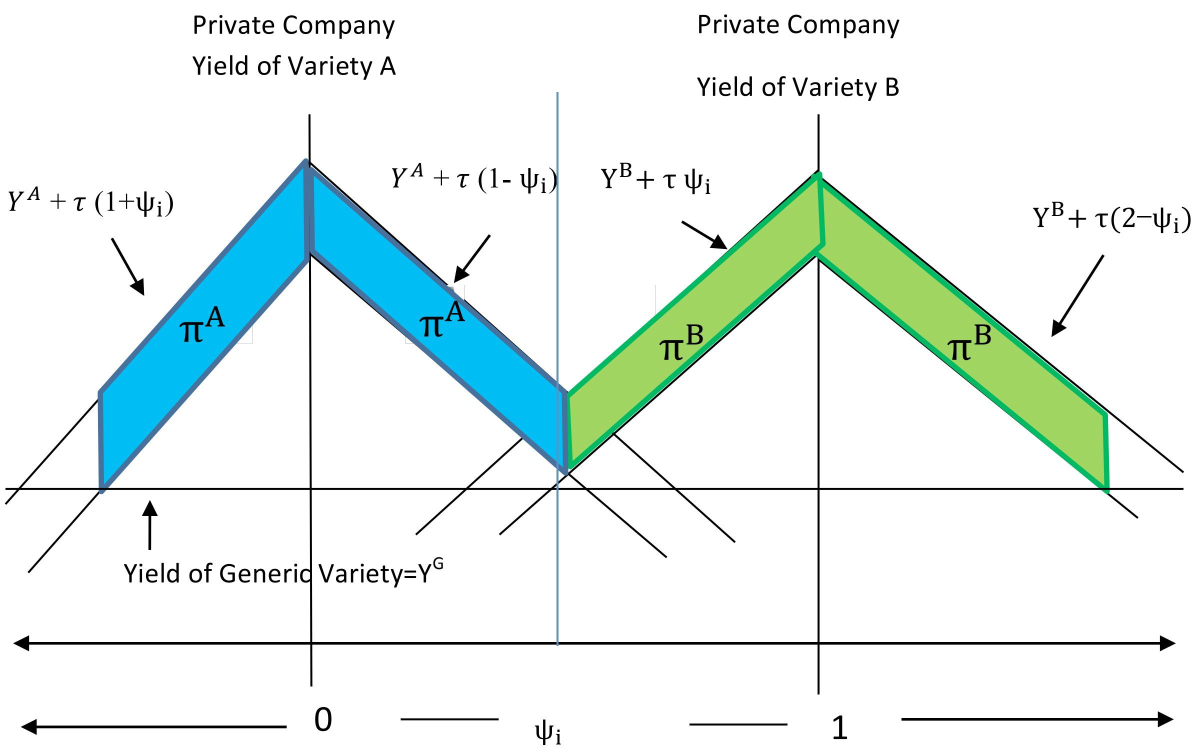

Figure 3.2 Horizontal Location Model –Two Private Companies
Source: Author

Taking a first order condition from equation 3.14 and solving for price w^A and taking first order condition from equation 3.15 and solving for price gives best response functions for each firm, given by:

$$R^a = \frac{2Y - 2Y^G + 3\tau + w^B}{6} \tag{3.16}$$

and

$$R^b = \frac{2Y - 2Y^G + 3\tau + w^A}{6} \tag{3.17}$$

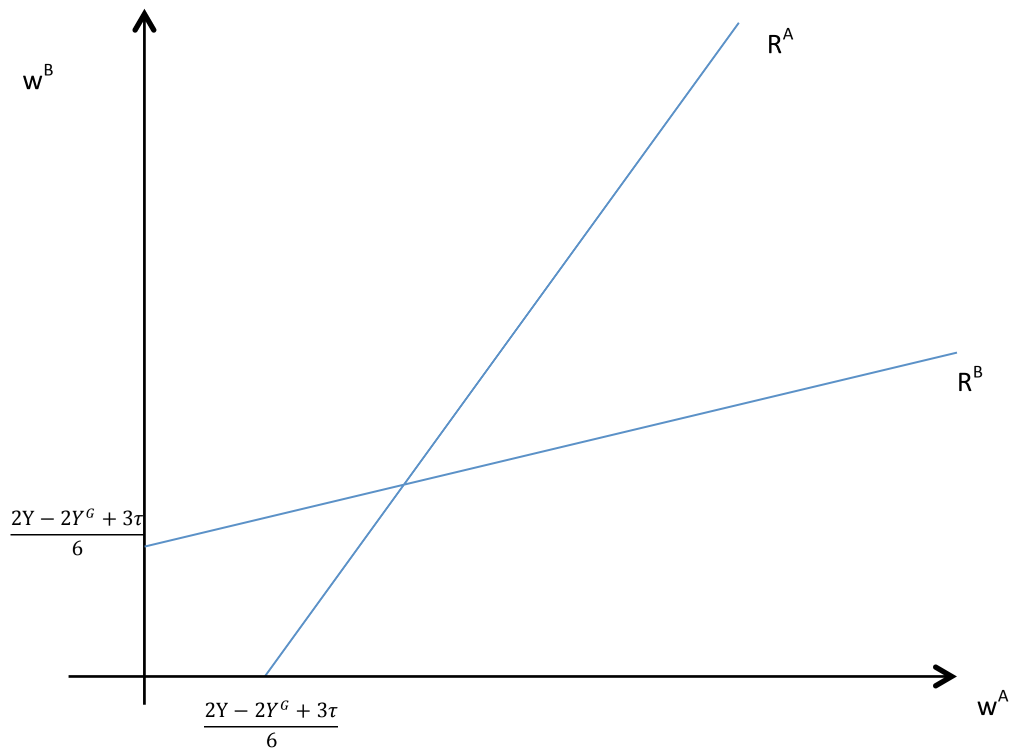

Figure 3.3 Best response functions – pricing by two private companies
Source: Author

The Nash equilibrium pricing[11] occurs at the point of crossing of company *A*'s and company *B*'s best-response functions, and is equal to:

$$w_0{}^A = \frac{2Y - 2Y^G + 3\tau}{5} \tag{3.18}$$

and

$$w_0{}^B = \frac{2Y - 2Y^G + 3\tau}{5} \tag{3.19}$$

The market demands for variety *A* and *B* respectively are given by:

$$Q^A = \frac{6Y - 6Y^G + 9\tau}{10\tau} \tag{3.20}$$

[11] If a horizontal location model in a range *0-1* with two competing varieties were used, as both prices increased welfare would remain constant. That is not what we observe in the real world.

$$Q^B = \frac{6Y - 6Y^G + 9\tau}{10\tau} \quad (3.21)$$

As can be observed on Figure 3.3, the two varieties are strategic complements. As price of one variety increases the price of the other variety also increases (Bulow et al. 1985).

3.3.2 Scenario Two: Case of Public Company and Private Company

In the second scenario, a private company competes with a public company. The variety *A* is owned by a public company, whereas, variety *B* is owned by a private company. In this exercise, the objective of a public company is to maximize total economic surplus. The objective of the private company, as before, is to maximize profit. With constant output price P[12], downstream impacts on consumer welfare are also assumed to be *zero*. Recall there is an assumption for P to be equal to *1* for simplicity reasons. The economic surplus is made up of the producer surplus of both breeding companies, and the surplus of growers who purchase the varieties *A* and *B*. The effects on the growers' surplus, or the welfare impacts, are calculated in the related input market, without taking into consideration the other input markets. The total surplus maximized by the public company is captured on a Figure 3.4. Starting from the left hand side on Figure 3.4, growers with land characteristic $\hat{\psi}_i < 0$ have surplus given by triangle *M*. The bottom length of the triangle *M* is equal to demand on this margin $\frac{Y - Y^G + \tau - w^A}{\tau} = -\hat{\psi}_i^{A,G}$, the slope of the revenue and profit curve is τ, therefore, the area of the triangle *M* is given by $\frac{1}{2}\tau\left(\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)^2$. On the other margin growers' surplus is not only a triangle *N* but also rectangle *Q*. Therefore, total area maximized on this margin is the grower surplus given by triangle *N* $\frac{1}{2}\tau\left(\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)^2$ plus remaining grower surplus *Q* and breeder surplus *R*. The sum of rectangles *Q* and *R* is $\left(\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)\left(\mathbf{Y} + \boldsymbol{\tau} - \boldsymbol{\tau}\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)$. Following the same logic, producer and breeder surplus for variety B on variety B's private margin is given by triangle *O* with area $\frac{1}{2}\tau\left(1 - \frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)^2$ plus remaining grower surplus *S* and breeder surplus *T*. The sum of rectangle *S*

---

[12] Price taking assumption is a reasonable assumption given production from any given variety relative to the size of the global market place. For instance, total production from Canada and Australia each make up less than 4% of the world wheat market.

and T has an area $\left(1-\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)\left(Y+\tau-\tau\left(1-\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)\right)$. A remaining area which has to be included is a breeder surplus on the external margin of the public company, rectangle V, given by $\left(\frac{Y-Y^{G}+\tau-w_0{}^{A}}{\tau}\right)w_0{}^{A}$. The external margin of variety B is not directly affected by public company price.

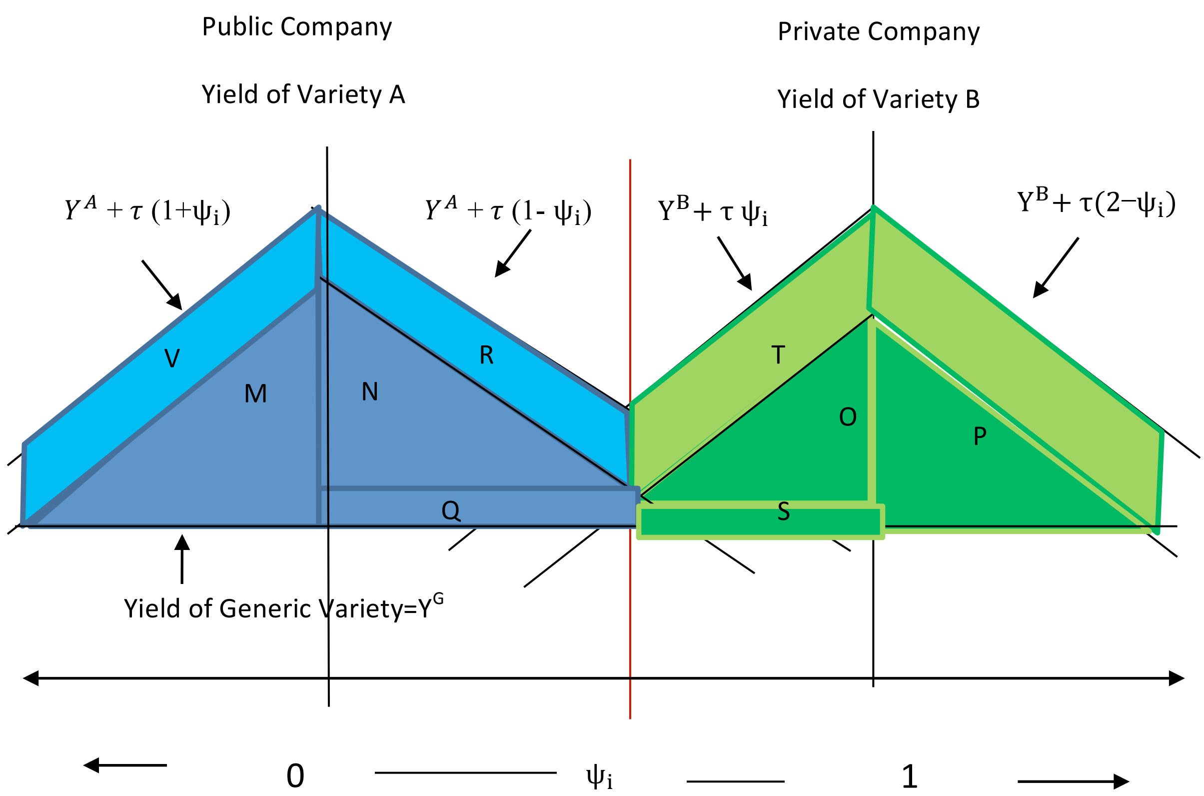

Figure 3.4 Horizontal Location Model - Public and Private Company

Source: Author

$$\textbf{Total Surplus}=\frac{1}{2}\tau\left(\frac{Y-Y^{G}+\tau-w_0{}^{A}}{\tau}\right)^2+\frac{1}{2}\tau\left(\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)^2+\frac{1}{2}\tau\left(1-\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)^2$$

$$+\left(\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)\left(Y+\tau-\tau\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)$$

$$+\left(1-\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)\left(Y+\tau-\tau\left(1-\frac{\tau-w_0{}^{A}+w_0{}^{B}}{2\tau}\right)\right)+\left(\frac{Y-Y^{G}+\tau-w_0{}^{A}}{\tau}\right)w_0{}^{A}$$

(3.22)

Taking first order condition and solving for price gives company *A*'s best response function:

$$R^{a} = \frac{{w_0}^{B}}{3}. \quad (3.23)$$

Company *A*'s reaction function shows that the public company should charge one third of the price of the competing private company. This is a novel result, which suggests that the public company, to maximize total surplus, should price above the marginal cost. Private company *B* is profit maximizing and its objective function and best response function are the same as in the previous section. Recall

$$R^b = \frac{2\mathrm{Y} - 2Y^G + 3\tau + w^A}{6}.$$

The best response functions are graphed on Figure 3.5. Similar to the previous scenario, varieties are strategic complements. Increase in price of one variety causes increase in price of a second variety.

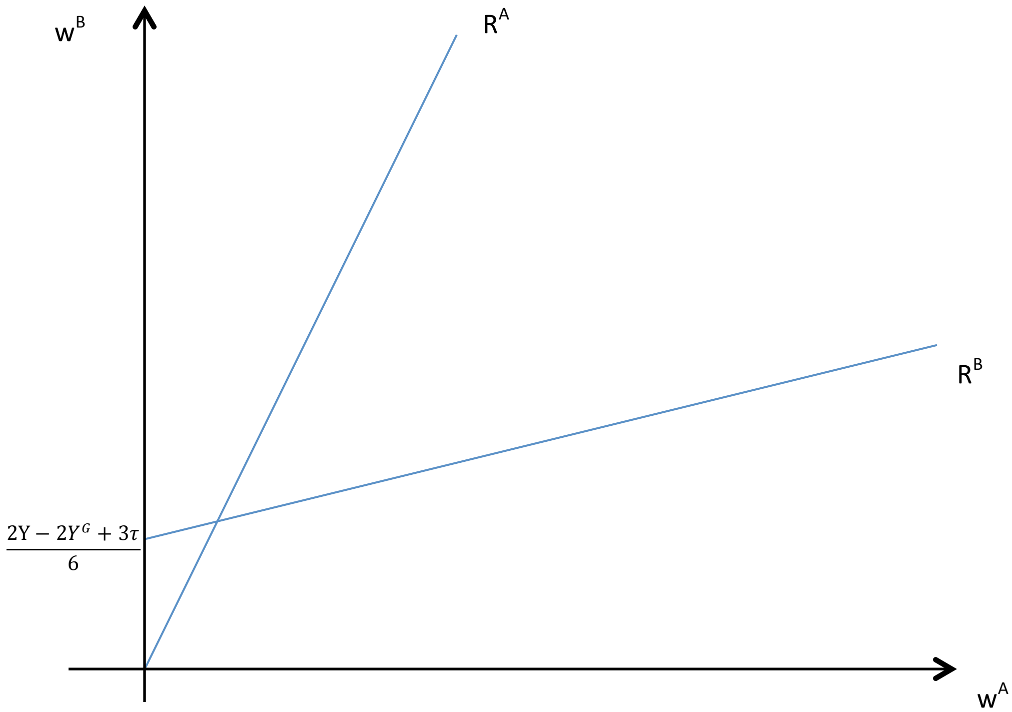

Figure 3.5 Best Response Functions – Pricing by Public and Private Companies
Source: Author

Deriving the same result from minimizing two Dead Weight Losses (DWL) in the Malla and Gray (2005) model provides additional insight and explanation into the novel result. As illustrated in Figure 3.6, there are two sources of DWL. The first DWL represented by area *Y*, comes from charging by the public company the price w^A *higher* than the marginal cost. The second DWL represented by area *Z*, comes from moving away from the optimal demand distribution between varieties *A* and *B* by charging different prices for varieties. If the public company charges a price equal to the marginal cost (marginal cost *L=0*) and a competing private company charges a price above marginal cost, as we know they do, some growers are going to choose the public variety because it is cheaper, even if the private variety is better suited for their land type and has potential to increase their yield and social surplus. If prices of both companies were equal, farmers would choose varieties with optimal yield for their land type and the DWL captured by triangle *Z* would be *0*[13]. The public firm must consider DWL, *Y* and *Z.* Given the

[13] If Hoteling model in range 0-1 was used the public company would match the private company's price therefore public company would behave the same as private company.

private firm is pricing above marginal cost, the public firm will minimize the sum of DWL in the market by pricing one third of the way between the private firm's price and the generic price of zero.

The optimal price of the public company is twice as close to zero (to marginal cost) as it is to the private company's price because the demand on the generic margin is twice as elastic as the response on the private variety margin. This optimal pricing above marginal cost relates to the theory of Second Best (Lipsey and Lancaster 1956). According to the theory of Second Best, if one of the Pareto optimum conditions cannot be satisfied, the second best optimum outcome is reached by moving away from some other optimum conditions (Lipsey and Lancaster 1956). If the distortion cannot be removed, adding more distortions will result in the distortions cancelling out each other out and will produce a more efficient outcome. Since introduction of IPR protection gave the private wheat breeding company market power to price above marginal cost, and this distortion is uncorrectable, the public firm can create a second best optimum condition by creating a second distortion and charging a price above marginal cost. The social surplus is higher with both distortions than it would be with one.

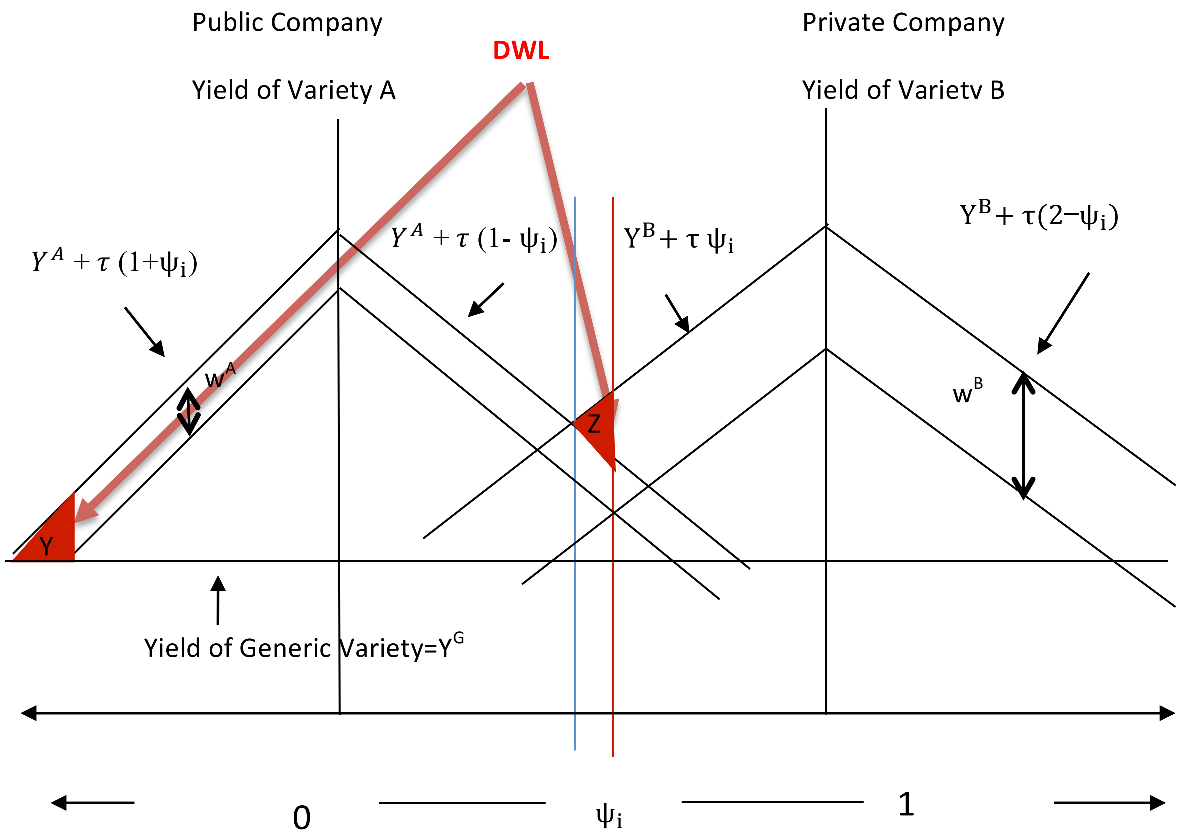

Figure 3.6 Horizontal Location Model - Public and Private Company (DWL)
Source: Author

Mathematically minimizing DWL

$$\mathrm{DWL} = \frac{1}{2} w_0{}^{\mathrm{A}} \left(\frac{Y - Y^G + \tau}{\tau} - \frac{Y - Y^G + \tau - w^A}{\tau} \right) + \frac{1}{2} (w_0{}^{\mathrm{B}} - w_0{}^{\mathrm{A}}) \left(1 - \frac{\tau}{2\tau} - 1 + \frac{\tau - w_0{}^{\mathrm{A}} + w_0{}^{\mathrm{B}}}{2\tau}\right) \tag{3.24}$$

FOC

$$w_0{}^{\mathrm{A}} = \frac{w_0{}^{\mathrm{B}}}{3} \tag{3.25}$$

The private company is also profit maximizing. Recall, the best response function of company *B* is

$R^b = \frac{2Y - 2Y^G + 3\tau + w^A}{6}$

The Nash equilibrium pricing takes place at the point where company *A*'s and company B's best-response functions cross

$$w_0{}^{A} = \frac{2Y - 2Y^G + 3\tau}{17} \quad (3.26)$$

and

$$w_0{}^{B} = \frac{6Y - 6Y^G + 9\tau}{17}.. \quad (3.27)$$

The Public Firm as a Stackelberg Leader

If one thinks of the actions of the public firm as public policy, then it is consistent to think of the public firm as a Stackleberg leader in pricing that sets price to maximize social surplus, fully anticipating the reaction of the private firm. Typically it is assumed the government is setting policy and then the companies are reacting to it. The government is therefore the Stakleberg leader because they can set policy rather than react to what the private firm does. This fits to the situation of some industries such as telecommunications and electricity, which are former public monopolies who have a first mover advantage (Fjell and Heywood 2002). Therefore, it seems to be worth consideration whether the public wheat breeding company is a Stackelberg leader with first mover advantage. If we assume the public company has a leading position and acts as a Stackelberg leader, whereas, the private company is a follower, the game would be solved by backward induction.

Stage 2

The follower, which is a private company *B* is setting its price by solving a profit maximizing objective function. From the previous section, we know company *B's* profit function and company *B's* best response function which is: $R^b = \frac{2Y - 2Y^G + 3\tau + w^A}{6}$.

Stage 1

The public company sets and commits its price, knowing behaviour of the private company. The public company solves total surplus maximizing equation 3.28 subject to company *B's* best response function. In this situation the public company maximizes not only the direct impact of its price on social surplus but also the indirect impact through price of the private company (adding surplus on external margin of company *B*).

$$\textbf{Total Surplus} = \frac{1}{2}\tau\left(\frac{Y - Y^G + \tau - w_0{}^A}{\tau}\right)^2 + \frac{1}{2}\tau\left(\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)^2 + \frac{1}{2}\tau\left(1 - \frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)^2$$

$$+\left(\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)\left(Y + \tau - \tau\frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)$$

$$+\left(1 - \frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)\left(Y + \tau - \tau\left(1 - \frac{\tau - w_0{}^A + w_0{}^B}{2\tau}\right)\right) + \left(\frac{Y - Y^G + \tau - w_0{}^A}{\tau}\right)w_0{}^A$$

$$+\frac{1}{2}\tau\left(\frac{Y - Y^G + 2\tau - w_0{}^B}{\tau} - 1\right)^2 + \left(\frac{Y - Y^G + 2\tau - w_0{}^B}{\tau} - 1\right)w_0{}^B$$

Subject to: $w_0{}^B = \frac{2Y - 2Y^G + 3\tau + w^A}{6}$ **(3.28)**

Taking first order condition and solving for $w_0{}^A$ gives us

$$w_0{}^A = \frac{2Y - 2Y^G + 3\tau}{33} \tag{3.29}$$

Using company *B's* best response function, we get price of the private company.

$$w_0{}^B = \frac{34Y - 34Y^G + 51\tau}{99} \tag{3.30}$$

Comparing the equilibrium prices (equations 3.29 and 3.30) to Nash equilibrium prices from above where both companies were equal (equations 3.26 and 3.27), we can observe that if the public company has a Stackelberg leader position in the market, prices are slightly lower compared with prices when there is an equal position of both firms. These outcomes suggest that the ability of the public company to move first and commit to its actions is beneficial for social surplus and increases efficiency with which the public company fulfills its objectives of maximizing social surplus. If the public company has a leading position it has more flexibility to maximize social surplus.

The concept of "Second Best" also applies to this situation. Granting the public company leading position creates a second distortion, which reduces the effect of the distortion already present in the market caused by IPR protection of wheat breeding activities.

The result of lower prices of publicly owned company is consistent with findings of Thomsen and Pedersen (2000), which found that companies with public shareholders have lower return to assets.

3.3.3 Scenario Three: Case of a Producer Owned Company and Private Company

Finally, in the third considered scenario a private company competes with a producer owned company. The objective of a producer-owned company is to maximize the economic surplus from the sale and use of their own variety. The producer owned company places no weight on the surplus of private company *B* or the surplus of growers buying variety *B*. The effects on the growers' surplus, or the welfare impacts, are calculated in the related input market, without taking to consideration the other input markets.

The surplus maximized by the producer owned company is captured on Figure 3.7. Starting from the left side, growers with land characteristic $\psi\hat{}_i < 0$ have surplus given by triangle *P*. The area of the triangle *P* is given by $\frac{1}{2}\tau\left(\frac{\mathrm{Y}-Y^G+\tau-w_0{}^{\mathrm{A}}}{\tau}\right)^2$. On the other margin, growers' surplus is given by triangle *Q* with the area given by $\frac{1}{2}\tau\left(\frac{\tau-w_0{}^{\mathrm{A}}+w^B}{2\tau}\right)^2$, and rectangle *R*. Producer surplus is given by rectangles *S* and *T*. The sum of rectangles *R* and *T* is given by $\left(\frac{\tau-w_0{}^{\mathrm{A}}+w_0{}^{\mathrm{B}}}{2\tau}\right)\left(\mathrm{Y}+\tau-\tau\frac{\tau-w_0{}^{\mathrm{A}}+w_0{}^{\mathrm{B}}}{2\tau}\right)$. Rectangle *S* is given by $\left(\frac{\mathrm{Y}-Y^G+\tau-w_0{}^{\mathrm{A}}}{\tau}\right)(\mathrm{w}_0{}^{\mathrm{A}})$.

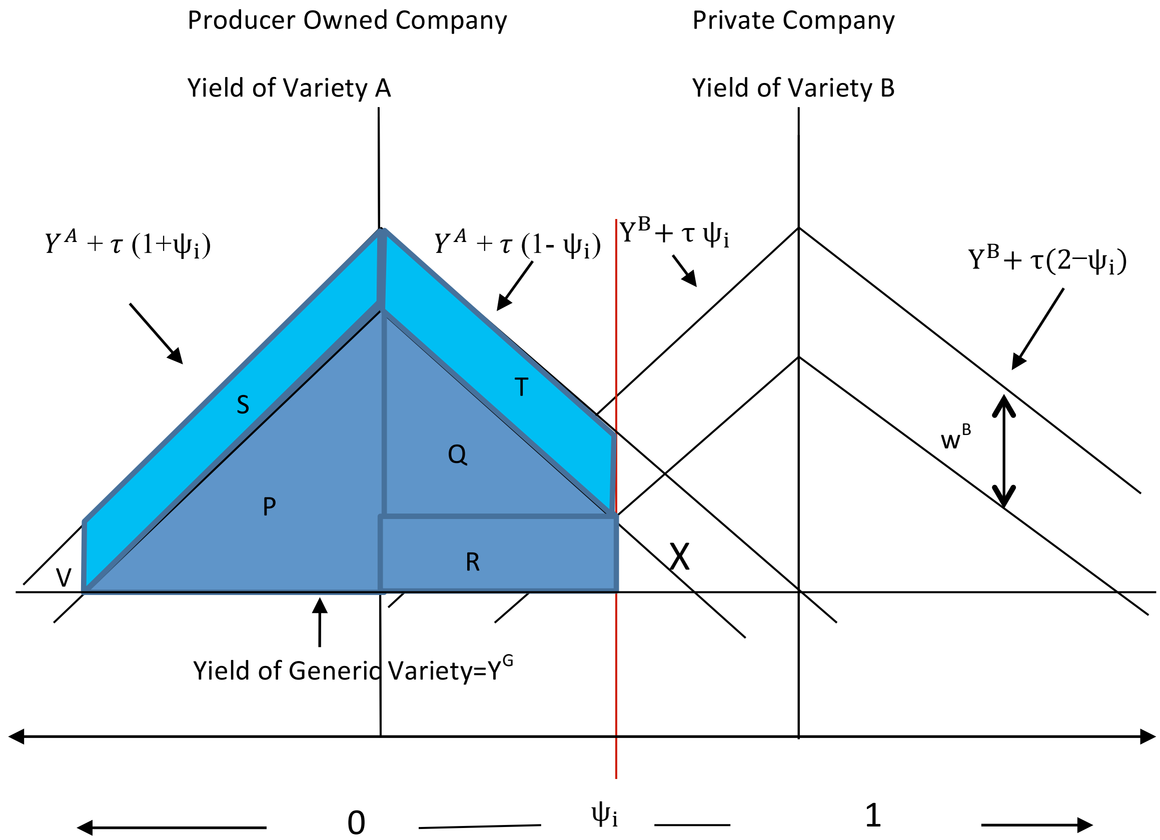

Figure 3.7 Horizontal Location Model – Producer Owned and Private Company
Source: Author

Therefore total considered surplus is:

$$\boldsymbol{Surplus} =$$
$$\frac{1}{2}\tau\left(\frac{\tau-w_0{}^A+w^B}{2\tau}\right)^2+\frac{1}{2}\tau\left(\frac{Y-Y^G+\tau-w_0{}^A}{\tau}\right)^2+\left(\frac{\tau-w_0{}^A+w_0{}^B}{2\tau}\right)\left(Y+\tau-\tau\frac{\tau-w_0{}^A+w_0{}^B}{2\tau}\right)+\left(\frac{Y-Y^G+\tau-w_0{}^A}{\tau}\right)(w_0{}^A) \tag{3.31}$$

Taking first order condition and solving for price give best response function

$$\boldsymbol{R^a} = \frac{-2Y-\tau+w^B}{5} \tag{3.32}$$

However, the price which we are looking for must be greater than or equal to zero, the objective function is subject to following constraint: $w^A>=0$

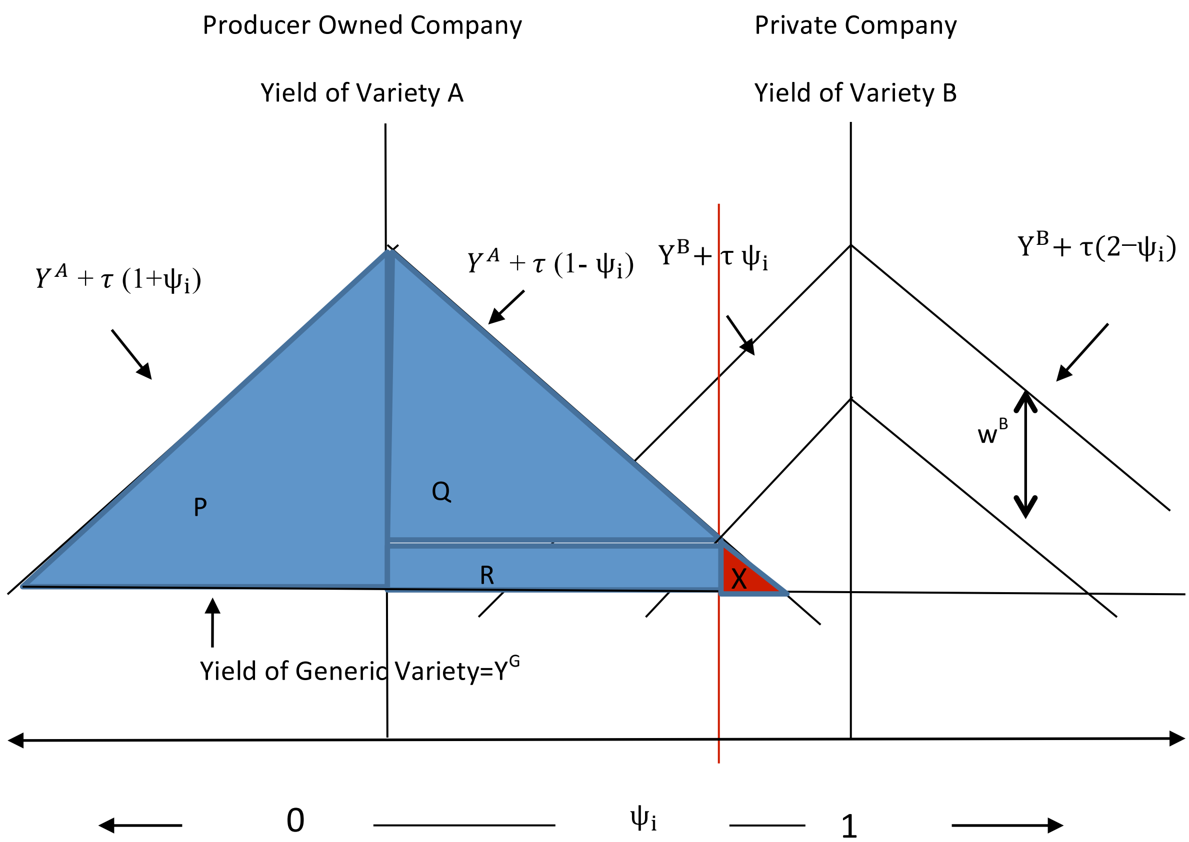

Figure 3.8 Horizontal Location Model – Producer Owned and Private Company #2.
Source: Author

Figure 3.7 captures the area, which the producer owned breeding company tries to maximize. The area is maximized when triangles *V* and *X* are captured. Therefore, let's consider lowering price $w_0{}^A$. When looking at Figure 3.8 we see that at $w_0{}^A = 0$, triangle *X* is still not captured. In order to capture it, the price charged by the producer owned company would have to be negative. Since price cannot be negative the best possible outcome is at $w_0{}^A = 0$. At this price the producer owned firm would not generate revenue for future investment in R&D. I do not model the required minimum revenue; it was assumed that the producer owned company, similar to GRDC in Australia, is funded by levies and it has been left outside of this model.

Mathematically minimizing Dead Weight Loss given by triangle V on Figure 3.7

$$\mathrm{DWL} = \frac{1}{2} \mathrm{w_0}^{\mathrm{A}} \left(\frac{\mathrm{y^A - y^G + \tau}}{\tau} - \frac{\mathrm{y^A - y^G + \tau - w_0{}^A}}{\tau} \right) \tag{3.33}$$

FOC

$$w_0{}^A = 0 \quad (3.34)$$

The private company's objective function and best response function is the same as before. Recall:

$$R^b = \frac{2\mathrm{Y} - 2Y^G + 3\tau + w^A}{6}$$

Consequently, the Nash equilibrium pricing for both companies are

$w_0{}^A = 0$, and

$$w_0{}^B = \frac{2\mathrm{Y} - 2Y^G + 3\tau}{6} \quad (3.35)$$

The three above scenarios gave different price levels. Having two private companies competing with each other in the market for wheat varieties results in prices of the varieties given by equations 3.18 and 3.19 being at a higher level than they would be if one of the companies were publicly or producer owned. Having a public company competing with a private company revealed some novel results. In order to maximize total yield, the public company should price above marginal cost when the competing private company prices above marginal cost. This result is related to the theory of "Second Best". The distortion from charging prices above marginal cost by the private company can be reduced by creating second distortion and charging a price above marginal cost by the public company. Obtained prices under this scenario are given by equations 3.26 and 3.27. Furthermore, if the public company is given a Stackelberg leading position, both companies will still price above marginal cost, however, prices will be lower than in the case where nobody has the leading position. Prices in this situation are given by equations 3.29 and 3.30. Finally, the obtained results suggest the producer owned company, in order to maximize growers' and breeder's surpluses in the market for variety A, should price at $w^A = 0$. The price charged by the private variety under this scenario is given by equation 3.35. The third scenario with the producer owned company and the private company in the market prices is the lowest among all three scenarios.

As we consider that wheat-breeding companies are introducing new varieties, we could expect that prices charged by companies will create different price series and different total surplus over time depending on ownership.

3.4 Variety Improvement and Its Pricing

Due to the efforts of breeding, there is a very general pattern of yield increase over time in a wide range of crops. New and higher yielding varieties will be adopted and replace older and lower yielding crop varieties. New wheat varieties typically have at least one and often two recent elite varieties as a parent. The progress made in the development of a new variety creates the basis for next varieties. Consequently, the plant breeding process is both sequential and cumulative, as new varieties intend to keep the desirable characteristics of the varieties they are built on at the same time trying to add new desirable qualities.

A new variety that provides greater value to growers creates scope for the breeder to charge a higher royalty. Subsequent varieties with higher yields or more attributes can command even higher prices.

Table 3.1 Prices under each Scenario

	Scenario 1(two private companies)	Scenario 2(company *A* is public, company *B* is private)	Scenario 3(company *A* is producer owned, company *B* is private)
Price of Company A	$w_0{}^{A} = \frac{2Y - 2Y^G + 3\tau}{5}$	$w_0{}^{A} = \frac{2Y - 2Y^G + 3\tau}{17}$	$w_0{}^{A} = 0$
Price of Company B	$w_0{}^{B} = \frac{2Y - 2Y^G + 3\tau}{5}$	$w_0{}^{B} = \frac{6Y - 6Y^G + 9\tau}{17}$	$w_0{}^{B} = \frac{2Y - 2Y^G + 3\tau}{6}$
The increase in $w_0{}^{A}$ as yield increases	2/5dY	2/17dY	0
The increase in $w_0{}^{B}$ as yield increases	2/5dY	6/17dY	2/6dY

Source: Author

The prices obtained in the previous section are presented in Table 3.1 and are shown to be a linear function of yield. Recall, the yield of variety *A* and *B* is assumed to be equal. Also wheat price *P* was assumed to be equal to 1. If the generic yield is constant as the yield of variety *A* and *B* increases the price of private firm *B* will increase by *P2/5dY*, *P6/17dY*, *P1/3dY* in Scenarios 1, 2 and 3, respectively. This implies that if yield of the differentiated varieties are sequentially increasing over time, the price impact of different ownership structures will increase over time.

If we assume yield of varieties *A* and *B* increase by one unit (t/ha), in Scenario 1 both prices are going to increase by 0.4 $/t. In Scenario 2, as yield of variety *A* and *B* increase by one unit (t/ha) the public company increases its price by 0.12 $/t and the private company increases its price by 0.35$/t. Finally, in Scenario 3 as yield of variety *A* and *B* increase by one unit (t/ha), the producer owned company still prices at 0 and the private company increases its price by 0.33$/t. The rate of increase in prices is different among scenarios. The fastest rate of increase is under Scenario 1 with two private companies. The slowest rate of price increase is under Scenario 3 with a producer owned and a private company. It can be concluded that over time as yield of varieties continue to increase, differences among prices under each scenario will grow. Using values of parameters presented in Table 3.2, and approximated based on data, total surplus under each scenario was simulated.

Table 3.2 Parameters

Parameters	**Values**
Y* - yield (t/ha)	3
P – price of wheat ($/t)	150
Y^G - yield of generic variety (t/ha)	2.8
τ	0.5

Source: Author

The values obtained from a simulation of total economic surplus (surplus of breeding companies and growers' surplus) calculated from the model, are presented in Table 3.3.

Table 3.3 Simulated Total Surplus

	Scenario one *Private - Private*	*Scenario two* *Public - Private*	*Scenario three* *Producer - Private*
Total Surplus	752.43	773.30	773.28

Source: Author

As presented in Table 3.3, the highest total surplus is obtained under Scenario 2 where a private company competes with a public company. This is not unexpected since the public company is assumed to operate with the objective to maximize total surplus. The lowest total surplus is under Scenario 1, where two private companies compete with each other. Total surpluses under Scenario 2 and 3 are very close. The differences in the obtained levels of social surplus in all three cases are small.

As yield of varieties increase, divergences in level of prices under each ownership scenario become greater, similar to the divergence between total surpluses under each scenario. Consequently, as plant breeding delivers higher yielding varieties, over time, the ownership and nature of competition in the market is expected to have a greater impact on social surplus.

3.5 Summary and Concluding Comments

In this chapter, the horizontal differentiation model has been solved for three scenarios of the wheat breeding market. The purpose of solving three scenarios and comparing them was to analyze how ownership of wheat breeding programs will affect pricing of varieties and what it means for total surplus.

The first scenario analyzes an oligopoly model of a wheat breeding market with two private companies. Having two private companies competing with each other in the market for wheat varieties results in prices of the varieties being higher than they would be if one of the companies were public or producer owned. Also the level of social surplus is the lowest under the first scenario.

The second scenario analyzes an oligopoly model with a public company competing with a private company. Having a public company competing with a private company revealed some novel results. In order to maximize social surplus, the public company should price above marginal cost when the competing private company prices above marginal cost. This result is related to the theory of “Second Best”. The distortion from charging prices above marginal cost by the private company can be reduced by creating second distortion, charging a price above marginal cost by the public company. Furthermore, if the public company is given a Stackelberg leading position, both companies will still price above marginal cost, however, prices will be lower than in the case where no firm has a leading position. If the public company is a Stackelberg leader, total surplus is increased. Again the theory of “Second Best” applies to this outcome. Adding distortion by interfering in the market and granting the public company Stackelberg leading position reduces total distortions in the market. In this scenario prices are lower than in the first scenario and social surplus is the highest among all three scenarios.

Finally, the third scenario analyzes an oligopoly model with a producer owned company competing with a private company. The obtained results suggest that the producer owned company, in order to maximize growers’ and breeder’s surpluses in the market for variety A, should price at $w^A=0$. Consequently under the third scenario prices are the lowest among all three scenarios. The simulated total surplus is higher than in scenario one with two private companies but lower than in scenario two with a public and private company in the market. At price 0, the producer owned company is not generating any revenue that could be used for reinvestment in R&D.

Based on the above analysis, it can be concluded that different objective functions assumed for different firm ownership will affect pricing behaviour. Therefore, the way Australian wheat breeding companies will act, whether as a private company, public company or producer owned company, will affect the welfare of Australian wheat growers and breeders. Public and producer ownership of a breeding program reduces prices in the market relative to prices with private ownership of breeding programs. GRDC’s and the state government’s power to influence InterGrain’s or AGT’s pricing behaviour might enhance social surplus by mitigating price increases over time. Additionally, over time as wheat breeding programs deliver higher yielding varieties, the importance of ownership is expected to be greater. Divergence in total surpluses and prices among scenarios of wheat-breeding programs' ownership is expected to grow. As Canada introduces UPOV 91 and is assessing various options to fund wheat breeding, including public sector and producers in wheat breeding has the potential to enhance price competition and social surplus.

Chapter 4

EPRs and the ADOPTION of WHEAT VARIETIES in WESTERN AUSTRALIA

4.1 Introduction

End point royalties are results of a strong form of intellectual property rights protection that allows breeders to collect a royalty for an innovation. The EPR rates charged on a wheat variety are essentially the price of using the genetics; therefore, EPR rates are directly related to the profitability of an innovation. Since profitability is one of the most important determinants in the decision to adopt an innovation (Griliches 1960; Lindner 1987), EPR rates have significant influence on the decision to adopt innovation.

Two examples of well-developed EPR systems exist in the Australian and French wheat breeding markets. Australian and French EPR systems are functionally quite different. The Australian EPR rates are set by the variety owners, consequently, the rates vary across breeding companies and varieties, but do not vary for any specific variety over time. The Australian EPR rate system was discussed in Chapter 2 of this dissertation. France has a uniform EPR rate system. A uniform EPR rate system is simpler to establish and to collect royalties than a varying EPR rate system. A shortcoming of the uniform system is that it removes the ability for a breeder to set the price on varieties, which is an important tactical decision for every company with market power. Those aspects of the French EPR system are discussed and compared to Australian system in Chapter 5 of this dissertation.

There does not appear to be relevant literature that has empirically estimated the impact of EPR rates on crop variety adoption. This Chapter will attempt to begin to mitigate that gap by providing an empirical estimation for Western Australia.

4.1.1 Chapter Objective

The objective of this Chapter is to develop and apply an appropriate empirical framework to estimate adoption curves of wheat varieties in Western Australia and to use the results to analyze the impact of EPR rates on variety adoption.

Figure 4.1 illustrates lifecycles of the dominant varieties adopted in Western Australia based on wheat variety adoption data from 1984 until 2011. As a variety is introduced to the market, typically it is adopted by only a few producers. Over time the variety's adoption increases until it reaches a maximum and then its adoption decreases until it becomes completely dis-adopted. As one variety is being adopted other varieties become dis-adopted. The extent of adoption depends on variety characteristics (presumably including EPR rates) and is analyzed in this chapter.

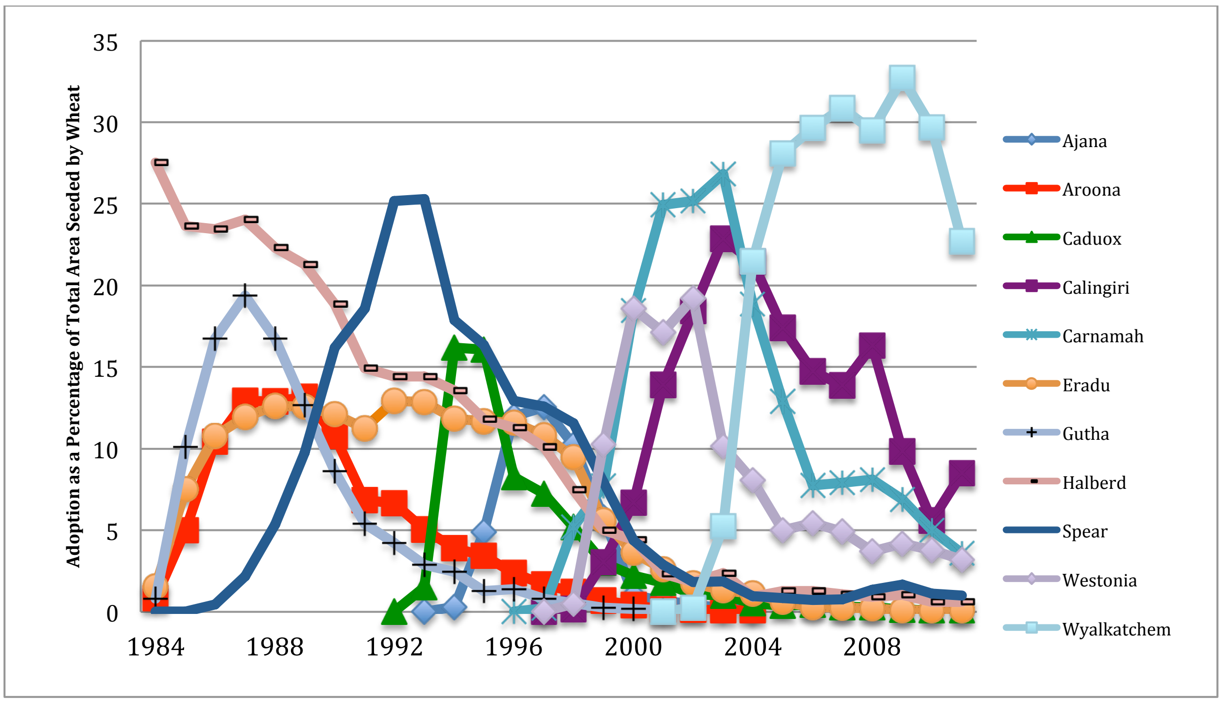

Figure 4.1 Lifecycles of Western Australian Superior Wheat Varieties

Source: Author based on data from Western Australia Wheat Variety Guide

4.1.2 Chapter Outline

Section 4.2 of this Chapter reviews the literature on adoption, analyzes characteristics of innovations, adopters and the dynamic nature of adoption patterns with a discussion on S shaped adoption curves. Section 4.3 introduces product lifecycles. Section 4.4 describes the theoretical and the empirical framework for the variety selection model. Section 4.5 describes the data. Section 4.6 presents an econometric model, the process of estimation and estimated model. The results are presented and discussed in Section 4.7. Finally, Section 4.8 provides a summary and conclusion.

4.2 S Shaped Adoption Models

An extensive search of the economic literature regarding innovation diffusion and adoption discovered a large number of studies in the technology adoption and diffusion field. Key studies on technology adoption and diffusion include: Griliches (1957, 1960), Rogers (1962, 1995), Rosenberg (1976), Lindner and Pardey (1979), Feder et al. (1985), Mahajan and Peterson (1985), Lindner (1987) and Mahajan et al. (1990b).

To define adoption, this study utilizes the famous work by Rogers (1962) who described adoption as an "innovation-decision process" through which a person decides if a new technology is worthy to adopt. In his seminal work, Rogers (1962) explored three distinct aspects of adoption; 1) the *characteristics of the innovation*, 2) the *characteristics of the adopters,* and 3) the *dynamic processes involved in the adoption decision*. Rogers' contributions to each of these aspects of adoption have provided a foundation for much of the theoretical and empirical research of adoption.

4.2.1 The Characteristics of the Innovation

Rogers (1962) described five *characteristics of the innovation* that determine the rate of adoption including: 1) *Relative advantage,* which assesses whether innovation has added benefits to its predecessor; 2) *Compatibility,* which determines whether the innovation meets existing values and norms; 3) C*omplexity,* which defines whether the innovation is difficult to understand or use; 4) *Trialability,* which outlines whether the innovation can be tested or sampled; and finally; 5) *Observability,* whether the results of adopting the innovation are visible to other individuals. According to Rogers (2002), “Innovations that are perceived by individuals as having greater relative advantage, compatibility, trialability, observability, and less complexity will be adopted more rapidly than other innovations” (p.990). Griliches (1957), pointed to *profitability* of innovation as being a deciding factor in the adoption decision. As noted by both of these seminal authors, adoption is an inherently dynamic process.

4.2.2 Characteristics of the Adopters

The adoption literature describes a number of characteristics of the adopters of innovation at different times in the product life cycle. Rogers (1962) categorized adopters into groups including *innovators*, *early adopters*, *early majority*, *late majority*, and *laggards*. Innovators are pioneers in the adoption of an innovation, whereas, laggards are the last to adopt. The first users are expected to have larger gain from the use of the product therefore, have a greater usage propensity (Mahajan et al. 1990a). Gatignon and Robertson (1985) based on their review of adoption research, noticed that new product innovators are likely to belong to heavy users of other products in the same category. The size of farm is one of the most common factors on which the empirical adoption literature has focused. Most studies found farm size and adoption to be positively correlated (Just and Zilberman 1983; Perrin and Winkelmann 1976; Diederen et al. 2003). The greater the scale of production, the higher is the opportunity cost of not adopting an innovation. Also farmers who have larger financial resources on their own are expected to adopt innovations earlier. Credit constraints may have a detrimental impact on adoption behaviour (Just and Zilberman 1983). With education and with experience the probability of becoming an early adopter increases (Wozniak 1987). On the other hand, younger farmers are more likely to be first to adopt or to be early adopters (Diederen et al. 2003). Age is associated with farm expertise. Older farmers will rely less on external information, and, hence, do not get exposure to innovations in the market as early as their younger colleagues. *Innovators* or *early adopters* use more information from mass media rather than interpersonal advice also they can be expected to use more publications as information sources (Diederen et al. 2003; Midgley 1976). Farmers who are involved in development of innovations are earlier adopters than those who just buy new technologies (Diederen et al. 2003). Feick and Price (1987) found that market experts, who assimilate and disseminate information on products, are usually more open to advertising and rely on media as information sources. Finally, earlier adopters have stronger leadership in shaping opinions about innovation. Since knowledge and experience are necessary to provide advice, earlier adopters are expected to be more involved in the evaluation process and in the purchase decision (Diederen et al. 2003; Feick and Price 1987).

Lindner (1987) reviewed the empirical research on adoption from different disciplines at the firm level and categorized these studies into two groups. The first category included the cross-sectional research with the key focus on why some producers adopt an innovation while others reject it. This is the dominant category of empirical studies on adoption. More recently Marra et al. (2003) listed examples of those studies listed by Marra et al. (2003) include: Shapiro et al. (1992), Smale et al. (1994), Nkonya et al. (1997). The second category included the time-based studies that analyze the factors influencing the timing of the adoption decision. This group of researchers try to explain reasons why some producers chose to be early adopters while others are laggards. The number of these studies is much smaller since the collection of data that can be used for such analysis is problematic. Examples of the research in this category include Lindner et al. (1982), Feder and Slade (1985), Lindner and Gibbs (1990), Foster and Rosenzweig (1995), Carletto et al. (1996), de la Briere (1996), and Burton et al. (1998).

4.2.3 The Dynamic Processes Involved in the Adoption Decision

Rogers (1962) also recognized five stages through which each person passes when making decisions about adoption: 1) *knowledge of an innovation*, 2) *forming an attitude toward the innovation*, 3) *decision to adopt or reject*, 4) *implementation of the new idea and 5) confirmation of decision.* There is a learning period in which producers choose whether to adopt a new product or not.

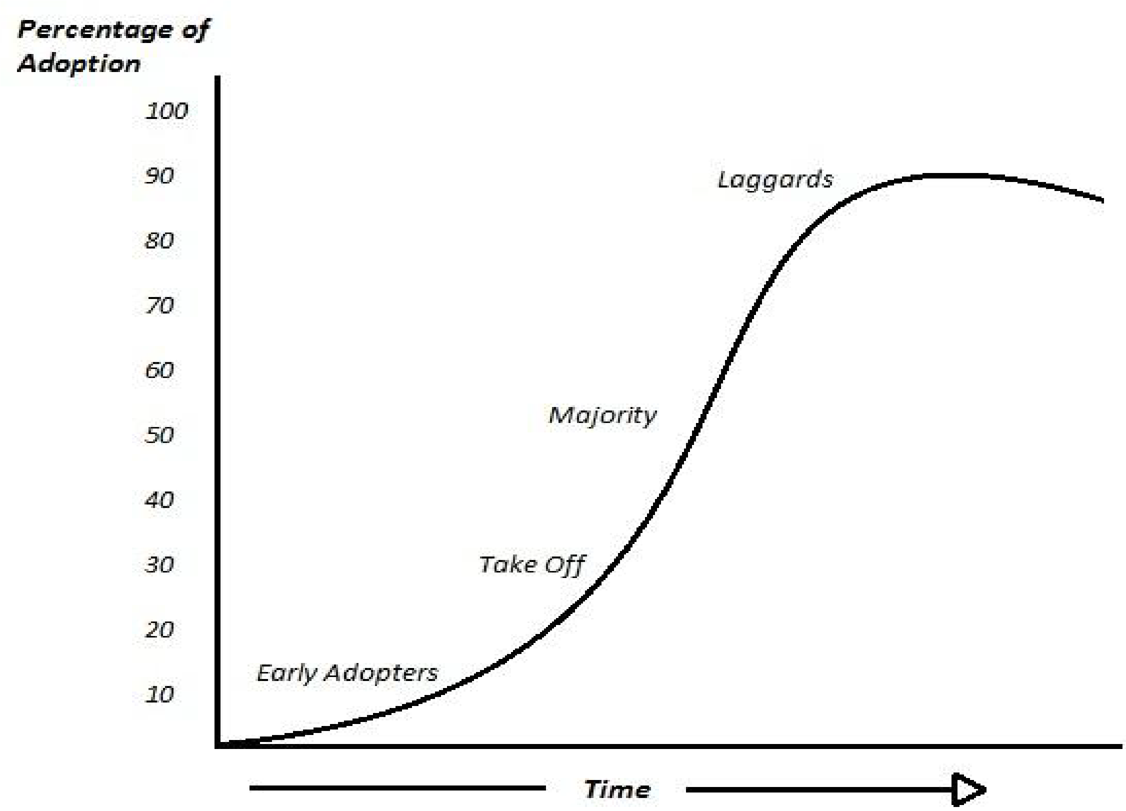

Figure 4.2 S Shaped Adoption Curve

Source: Rogers 1962

As information about innovation is passed along and individual adoption decisions are made, the innovation develops a diffusion path over time that is usually S-shaped. The diffusion path over time depends upon the rate of imitation in a particular environment. Mansfield (1961) hypothesized that the basic factors for the rate of imitation are: the number of firms currently using the innovation, the profits caused by adoption, the size of investment, and "other" determinants.

In terms of estimating S shaped curves, Griliches (1957) was the first to use the logistic function together with economic theory to estimate the diffusion of hybrid corn, which resembled an S shaped curve. Griliches used log-linear regression methods (logit), concluding after trying logistic and normal distribution models that a logistic function sufficiently fit the trend of the data, and is easier to interpret than the cumulative normal distribution. The results of his study indicated farmers have behaved in the way consistent with profit maximization therefore the diffusion of new corn hybrids depends upon farmers' expected profitability. A limitation of Griliches' S shaped adoption model is that it cannot accommodate dis-adoption, which occurs in a product cycle. When a new variety is being adopted, another variety must be dis-adopted. Dis-adoption is a replacement of one variety with a variety that is assumed to be better, more beneficial or more profitable (Dinar and Yaron 1992).

In the literature, the majority of the recent studies use the Bass (1969) diffusion model to capture the S-shaped curve of new product adoption. The Bass model has three main parameters: *the coefficient of innovation or external influence* (p), *the coefficient of imitation or internal influence* (q), and *the market potential (α or m).* The Bass model does not contain deterministic explanatory variables. Its specification is simple. Over the past 45 years many researchers have tried to develop the model in a number of ways. Researchers have tried to include marketing variables, supply restrictions, and multiproduct interactions, including time-varying parameters, replacement purchases, multiple purchases, or by analyzing cross-country diffusion patterns. The popular examples of improved Bass models include Norton and Bass (1987), Wilson and Norton (1989), and Mahajan and Muller (1996). Mahajan and Muller (1996) developed the Bass model in a way that allows for replacement and the market to grow from one generation to the next but does not allow for multiple purchases. The Mahajan and Muller model is suitable for studying adoption of durable goods to find the optimal time of introduction of an innovation.

4.3 The Product Lifecycle

Several studies have found that a product lifecycle model is more appropriate for estimating crop variety adoption over time. In the existing literature, Dahl et al. (1999) following Barkley and Porter (1996) undertook adoption research for wheat lifecycles. They built and estimated an econometric model of wheat adoption so as to capture the wheat lifecycle patterns. The Dahl et al. (1999) econometric model included a number of determinants, one of them being the years since a variety is released. To capture the adoption and dis-adoption lifecycle trends for wheat varieties, they used a polynomial approach by adding the squared and the cubic levels of the variable. This allowed Dahl et al. (1999) to measure the marginal impact of time since variety release on market share for wheat varieties, and also the mean years to maximum adoption, as well as the average time of a variety's lifecycle. Gambrell (2004) used a similar time trend variable in an econometric model to capture lifecycles of rice varieties grown in Texas. The estimated parameters allowed capturing all stages of a product's lifecycle, including adoption and dis-adoption. To describe the decision making process of a variety based on expected yield performance Gambrell (2004) developed a yield ratio. The yield ratio is comparing the yield of variety (*i*) to the yield of the next best alternative. Where (*i*) is equal to 1,…,N_t and N_t is the number of alternatives in period (*t*). If YR=1, the considered variety is the best variety or at least equally good as the next best alternative. If YR< 1, then the considered variety has a lower expected yield relative to the best alternative. Gambrell (2004) found the yield ratio had a positive impact on variety adoption. Gambrell (2004) also used a ratio to indicate the stability of yield for each variety. The stability of yield is an important factor in farmers' decision to adopt variety since unstable yields indicates a risk of having reduced yields. The variety with larger stability of yield provide greater confidence within varietal choice. Covey (2012) used Gambrell's model to estimate the value of variety testing in the Canadian Western Red Spring (CWRS) wheat market.

The research focusing on determinates of crop variety adoption has revealed that the perception a farmer has about the features of an innovation has a substantial impact on a farmer's decision to adopt (Adesina and Baidu-Forson 1995; Negatu and Parikh 1999; Lindner 1987). Barkley and Porter (1996) studied wheat variety adoption in Kansas and found that the most important determinates of wheat varieties were the yield, kernel quality, varietal age, and yield stability. Dahl et al. (1999) examined wheat variety selection in Canada and the United States and also found that yield has a significant influence the adoption decisions of wheat varieties. Dahl et al. (1999) found characteristics of a wheat variety that impact the quality of bread and other end products, are also important determinants of farmers' adoption decision, especially in Canada. Dahl et al. (1999) also found other things such as stem rust, leaf rust, and lodging could affect a farmer's choice of variety. They found that farmers prefer publicly released varieties to varieties released by the private sector.

4.4 Variety Selection Model

To capture the adoption pattern of wheat varieties in Western Australia it is necessary to choose the appropriate empirical model. In the literature there is a number of various adoption models, however, most are not suitable to estimate wheat variety adoption. Since the available data describes aggregate adoption levels, with no micro level data on individual adoption, many of the discrete choice models cannot be used. Moreover, aggregate pattern of wheat variety adoption in Western Australia is characterized by variety adoption and dis-adoption over time. New wheat varieties typically take several years to reach peak adoption and are then slowly dis-adopted as the new superior varieties enter the market place. During each year several varieties co-exist in the market and therefore, peak adoption is less than 100 percent. Although a specific variety is superior to other varieties in the market, the industry typically grows many varieties at one time. Possible reasons for using more than one variety include: various types of soil, climate, marketing contracts, different times to maturity, and the fact that the older varieties are more familiar and provide a certain level of security. An individual farmer may see growing a number of varieties as a source of diversification to reduce risk. In any case, in this mixture of variety adoption, the model should not have a pre-determined peak level of adoption for each variety equal to 100%.

As a result of these features of wheat variety adoption, this study requires a less restrictive model, which can consider the effects of multiple variety selection and can accommodate the complete life cycle of varieties. Therefore, the polynomial least squares model, used by Barkley and Porter (1996), Dahl et al. (1999), Gambrell (2004) and Covey (2012), is appropriate and is used for this study. One distinct advantage of this study over these previous studies using similar models is in estimating the impact of EPR rates on variety adoption.

Theoretical Issues

The process of developing the theoretical model begins with an examination of incentives facing a representative farmer selecting a wheat variety. This is consistent with analysis done in Chapter 3, however the model in this Chapter is more developed because it fits different purposes. Following Barkley and Porter (1996) and Dahl et al. (1999), a motivation for the empirical model is the neoclassical input characteristic model from the theory of the firm. The individual expectation of yield as well as the other benefits and costs of variety are a function of time since the variety has been released. Different farmers need different amounts of time with a variety in the market to establish their expectations about variety characteristics. Some farmers adopt a variety as soon as it is released while others wait to see how the variety will perform and decide to adopt in latter stages of the variety lifecycle. An individual farmer operating in a perfectly competitive market and under production uncertainty has expected profit function that may be expressed as:

$$\max_{x} \mathrm{E_{jt}} \quad (Profit)$$
$$= P_{wt}\sum_{i=0}^{n} E_j(Yield_i(t))x_{it} - \sum_{i=0}^{n} EPR_i E_j(Yield_i(t))x_{it} - \sum_{i=0}^{n} E_j(\delta_i(t))x_{it} - E_j\phi\sum_{i=0}^{n} x_{it}$$

Subject to $\sum_{i=0}^{n} x_{it} = X_{jt}$ (4.1)

where:

P_{wt} = wheat price;

$\sum_{i=0}^{n} E_j(Yield_i(t)) * x_{it}$ =expected wheat production in year t;

$EPR_i * E_j(Yield_i(t))$ = the expected cost of the i^{th} seed variety;

x_{it} = area seeded for i^{th} seed variety in year t;

$E_j(\delta_i(t))$= the expected non seed/yield cost/benefit of producing i^{th} variety;

$E_j\phi$ = the expected non variety specific production cost;

i=1...n varieties;

j=1...k farmers;

X_{jt}= the land available for farmer j in year t;

In the equation above, expected *total revenue* for each farmer is given by price of wheat (P_w) times total quantity produced (given by summation of products of *expected yield* of each variety where expectation is a function of the time variety is in the market) and *area seeded* to that variety, $\sum_{i=0}^{n} E_j(Yield_i(t))x_{it}$.

Expected *total cost* of wheat production for each farmer is given by summation of products of *EPR rates*, *expected yield* and *area seeded* for each variety ($\sum_{i=0}^{n} EPR_i E_j(Yield_i(t))x_{it}$). Moreover, there are expected input costs and/or benefits related to each specific variety and area seeded by that variety ($\sum_{i=0}^{n} E_j(\delta_i(t))x_{it}$) and expected cost not related to varieties but dependant on area seeded ($E_j(\phi) * \sum_{i=0}^{n} x_{it}$).

As a result of the separability assumption, the decisions about wheat varieties in this model are autonomous from the decisions about other crops. The farmer choses the proportion of wheat seeded to each variety to maximize expected profit.

If farmers were homogeneous, all would choose to adopt the same variety, but that is not the case in the Western Australian wheat market where numerous varieties are being adopted. Farmers are heterogeneous with a range of farm characteristics and a significant range in soil and climatic conditions. Farmers have different individual expectations about variety profits, and variety yields, which are both a function of time the variety is in the market. Using the concept of Bayesian learning, farmers attach different weights to their initial beliefs about varieties' characteristics and to new information that shows up with time. Consequently, farmers expect different yields and profits and, therefore, make different choices at different points in time.

The individual profit maximizing condition subject to land constraint is solved using the *Lagrange Function* represented by the equation below.

$$L_{jt} = P_w \sum_{i=0}^{n} E_j(Yield_i(t))x_{it} - \sum_{i=0}^{n} EPR_i E_j(Yield_i(t))x_{it} - \sum_{i=0}^{n} E_j(\delta_i(t))x_{it} - E_j(\phi) \sum_{i=0}^{n} x_{it} - \lambda_{jt}(X_j - \sum_{i=0}^{n} x_{it}) \qquad (4.1a)$$

FOC:

$$P_W\, E_j\big(Yield_i(t)\big) - \lambda_{jt} - E_j(\delta_i(t)) - E_j(\Phi) = EPR_j E_j\big(Yield_i(t)\big), \qquad (4.1b)$$

$$\lambda_{jt} = P_W\, E_j\big(Yield_i(t)\big) - E_j(\delta_i(t) - E_j(\Phi) - EPR_j E_j\big(Yield_i(t)\big) \qquad (4.1c)$$

The value of the marginal product of the variety must be greater than or equal to the price of seed. Given the linear nature of the Lagrange, the shadow value of the land for farmer *j*, λ_j will reflect the value of the best-suited variety. As such, condition 4.1 will hold for only the variety with highest expected gross margin for each farmer.

Based on the Aggregate Profit Maximization Theorem[14], the expected profit maximizing equation for the individual farmer can be aggregated to all farmers. If each farmer maximizes his/her profit, they collectively maximize aggregate profit. Following Barkley and Porter using an implicit function theorem, the demand for variety *i* (x_i) can be represented by:

$$X_{it} = x(P_W, \quad EPR_1, EPR_2 \ldots, EPR_M + \mathrm{E}\big(Yield_1(t)\big), \\ \mathrm{E}\big(Yield_2(t)\big) \ldots \mathrm{E}\big(Yield_M(t)\big), \mathrm{E}(\Phi), \mathrm{E}(\delta_i(t)\,)) \qquad (4.2)$$

where:

P_w = wheat price;
$\mathrm{E}(Yield_{i=1\ldots N}(t))$ =expected yield of the i^{th} variety and all competing varieties;
$EPR_{i=1\ldots N}$ = the cost of the i^{th} seed variety and all competing varieties;
$\mathrm{E}(\delta_{i=1\ldots N}(t))$= the expected non seed/yield cost/benefit of producing i^{th} variety and all competing varieties;
$\mathrm{E}\phi$ = the expected non variety specific production cost;
For $i = 1,\ldots n$, varieties,

[14] Jehle, G.A. and Reny, P.J. (2001) "Advanced Microeconomic Theory" second edition, page 207.

4.5 Data

The data used in this analysis comes from Western Australia Wheat Variety Guides and DAFWA are discussed below.

4.5.1 Dependent Variable

The dependent variable in this study, similar to studies by Dahl et al. (1999), Gambrell (2004) and, Covey (2012), is area seeded by each variety expressed as a percentage of total area seeded to wheat in Western Australia. This relates to Eq. 4.2 by observing that the seed use per acre is basically constant among wheat varieties. The amount of variety *i* used translates directly to the area seeded by variety *i*. Since the entire area seeded by wheat as a result of exogenous dynamics varies from year to year, when the area seeded by variety *i* is divided by the entire area, it derives the share of area seeded by each variety per year that is the dependent variable in this study. The choice of dependent variable enabled capturing the lifecycles of wheat varieties in Western Australia.

4.5.2 Independent Variables

The independent variables used in this model are listed below and were chosen based on the existing literature, economic theory and availability of data.

Yield Ratio

The variety's yield potential is one of the main factors determining wheat variety adoption (Barkley and Porter 1996; and Dahl et al. 1999; Gambrell 2004; Covey 2012). The importance of yield is determined by quality standards and norms for disease resistance applied to all varieties. Standards and norms make varieties quite uniform in terms of quality and disease resistance, leaving yield to differentiate varieties the most.

Higher yielding varieties ceteris paribus are expected to increase profits for farmers and therefore will face higher demand and higher adoption rates. When a new variety is released, a farmer decides whether it is more beneficial for him to switch to the new variety or stay with the current variety. If a new variety is performing better than existing varieties, it is expected the new variety will generate the higher revenue. An increase in expected total revenue provides incentives to the farmer to select the new variety. The increased revenue can either come from difference in the price or the quantity (yield) produced by the farmer, not necessarily both.

The yield index of each variety is obtained from the Department of Agriculture and Food Western Australia (DAFWA) and the Wheat Variety Guide, Western Australia 2012. DAFWA records the yield of wheat varieties planted in Western Australia as percentage of Gamenya in earlier years of the analyzed period of time and as a percentage of Wyalkatchem in later years. Yield data published in the Wheat Variety Guide, Western Australia 2012 is expressed as a percentage of Wyalkatchem. Since both sources of data were used, to make them comparable, yield data was adjusted to be expressed as a percentage of Wyalkatchem.

Finally, the Yield Ratio for this study is created in a way similar to the Gambrell and Covey studies where yield of each variety is divided by yield of the best alternative. The Yield Ratio is expected to have a positive impact on variety adoption. The yield stability wasn't included in this model because of lack of variability in yield data. Reported yield data was an average of yield for variety over a period of 5 years.

End Point Royalty Rates

The EPR rates are a focus of interest in this study. The EPR rate for each variety is set by the variety owner and is essentially a price for the variety. Farmers who purchase seed sign an agreement with an authorized seed distributor, which obligates the producer to pay a specified EPR at first point of sale of wheat for varieties protected by the Plant Breeders Rights Act to the variety owner (Breeding Company). Price has a direct impact on profitability of the variety, therefore, it is an important factor deciding adoption. The advantage of this study over studies by Covey, Gambrell and similar studies is that the data set includes EPR rates (prices) that usually are very difficult to access.

Based on economic theory, if the price of a normal good increases, the demand for that good decrease. Assuming wheat varieties are normal goods, the EPR rates are expected to have a negative impact on variety adoption.

The common problem of endogeneity of prices in estimation of demand does not apply to EPR rates because the EPR rate, set before seed is sold, does not change during the variety lifecycle. Therefore, EPR rates do not depend on realized adoption rates and the problem of endogeneity of prices does not exist in this situation.[15]

Maturity

Barkely and Porter (1996), Dahl et al. (1999) and Covey (2012) find days to maturity a significant factor in the decision to adopt or not. The maturity variable is evaluated by time when a variety is first planted to the point it is ready to harvest.

In Australia, varieties are classified according to maturity as Short, Short-Mid, Mid, Mid-Long, Long. This study uses a set of dummy variables to estimate whether time to maturity has a significant impact on variety adoption in Western Australia. In most of the places where wheat is grown, it is important that wheat reach its maturity before first frost. Since Western Australia has a warm climate, frost is not an issue, and average harvest takes place later than in other parts of the world. It is therefore unclear how these variables will affect adoption.

Disease Resistance

Disease resistance is another variable expected to have an impact on adoption decisions. Wheat is plagued by a wider assortment of diseases than other grain crops. Typically, recently developed varieties have better resistance than do older ones; however, that is not always true, and almost every variety has one or more deficiency. Many wheat growers plant a blend of two or more varieties because a mixture is more protected from diseases, weather, and insects. If one variety has a bad year, others may take up the slack. A study by Dahl et al. (1999), found disease resistance to have a positive impact on adoption.

Disease resistance to Septoria Nodorum Blotch, Yellow spot, Stem rust, Strip rust, Leaf rust, Powdery mildew, and Flag smut for adopted varieties is rated and reported in the Wheat Variety Guide and after calculating an average of disease resistance from the above categories, it

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[15] Endogeniety occurs when there is a contemporaneous correlation between an independent variable and the error term.

is used in this study. In the data set, disease resistance is expressed in the scale from 1 to 9 where: 1=Very susceptible, 2=Susceptible–Very susceptible, 3=Susceptible, 4=Moderately susceptible–susceptible, 5=Moderately susceptible, 6=Moderately resistant–moderately susceptible, 7=Moderately resistant, 8=Resistant–moderately resistant, 9=Resistant.

It is expected as the disease resistance increases, *ceteris paribus*, adoption of the variety will also increase.

Quality Factors

Growers increase expected profits by producing higher quality wheat with increased yields. Since quality controlling factors impact quality and yield potential, they may be important when considering a variety for adoption.

Wheat quality controlling factors such as hectoliter weight, grain plumpness, black point, seed size and sprouting tolerance are reported in the Wheat Variety Guides Western Australia and after calculating an average quality from the above categories, it is used in this study. These factors help control the end quality of wheat for each variety. Quality characteristics listed above were brought to average in order to obtain one Quality measure for variety. The scale of quality characteristics is from 1 to 9 where: 1=Extremely poor, 2=Very poor, 3=Poor, 4=Moderately poor, 5=Fair, 6=Moderately good, 7=Good, 8=Very good, 9=Excellent.

Quality factors are expected to have a positive sign in estimation results.

Time since Release

The time since a variety's release is expected to have an impact on the adoption. The more time a variety is in the market, the more information about the variety is present, reducing the risk of choosing variety, therefore, market share of variety increase with time. At some point, the variety reaches a peak of its adoption. Then, as new, better varieties enter the market and variety performance start to decline as a result of e.g. reduced disease resistance, the variety's market share starts to decline. Consequently, the time since release, the squared, and the cubic values of time since release are included in the regression. The time parameters are introduced to capture adoption and dis-adoption trends and therefore, to enable prediction of variety lifecycles. The estimated cubic function is expected to reflect all stages of adoption, the adoption, maturity, and dis-adoption of an average wheat variety (Dahl et al. 1999; Gambrell 2004; Covey 2012).

Wheat Price

The price of wheat influences growers' revenue and is likely to influence how much growers invest in the input market for a variety. This study uses Gross Value of Production from Western Australia (GVP AUD/t) as a wheat price. Wheat price is exogenous to adoption decision since Australian wheat production is 3%[16] of world wheat production and majority of produced wheat is exported therefore Australian production does not affect in significant way wheat price, and problem of endogeneity does not exist. The GVP data is obtained from DAFWA, covers GVP for categories other than feed and is deflated by the GDP deflator (annual %) in order to remove inflation.

The high yielding varieties are more profitable to adopt as the marginal benefit from a wheat (GVP) increase. Therefore interaction between deflated GVP and Yield ratio is created and it is expected as wheat price increases, *ceteris paribus*, adoption of the higher yielding varieties will also increase.

Variety Owner

The variety owner, a breeding company, and the breeders that develop the varieties, develop either a positive or negative reputation with some producers. As such the brand of variety can impact adoption. Previous studies found that producers prefer publicly developed varieties to private varieties (Dahl et al. 1999).

Protected by Plant Breeders Rights Act

If a variety is protected by PBR Act 1994, it means the variety has an enforceable EPR rate attached to it, and also, some legal restrictions on use and seed distribution of the variety.

[16] PricewaterhouseCoopers, 2011 The Australian Grains Industry, The Basics

Free to Trade

Not all varieties protected by the PBR Act have a restriction on grower-to-grower trade. Some varieties protected by the PBR Act can be subject to grower-to-grower trade if the variety owner allows it. Free to trade means there is no restriction on grower-to-grower variety trading.

Classification

Wheat Variety Guide Western Australia also provides classifications of varieties; Australian Hard, Australian Premium Hard, Australian Premium White, Australian Standard White, Australian Standard White Noodle, Australian Soft, Australian General Purpose and, Feed. Because these wheat classes have different end markets and potentially different market prices, it is possible to find relationship between variety choice and its classification. .

4.5.3 Data Sources

The wheat varieties' adoption data used in this study is collected from the state of Western Australia. Varieties' agronomic attributes and quality factors are appropriated from the Wheat Variety Guide Western Australia and records of DAFWA. The collected data, variable names and the sources of each data are presented in the Table 4.1 below.

Table 4.1 Data Source

Model Variable	Data	Data Source
Adoption	Percent of Seeded Acres	Wheat Variety Guide Western Australia 2008 -2012; DAFWA;
Yield Ratio$_1$	Estimates of Genetic Value (yield)	Wheat Variety Guide Western Australia 2010 -2012; The National Variety Trials (NVT); Statistical analysis of long term multi-environment trial (MET) data;
Yield Ratio$_2$	Wheat Yield Index	Wheat Variety Guide Western Australia 2010 -2012; DAFWA
Plant Breeder Rights	Dummy	Wheat Variety Guide Western Australia 2008 -2012;
Wheat Price	GVP$/t	DAFWA;
EPR	End Point Royalty rate $/t on wheat variety	Wheat Variety Guide Western Australia 2008 -2012; GRDC;
Time since Release	Years Since Variety's Release	National Variety Trail;
Hectoliter Weight,	Relative Scale Rating (1-9)	Wheat Variety Guide Western Australia

Grain Plumpness, Protein Content, Black Point		2008 -2012;
Seed Size, Sprouting Tolerance, Septoria Nodorum Blotch	Relative Scale Rating (1-9)	Wheat Variety Guide Western Australia 2008 -2012;
Yellow spot, Stem rust,Stripe Rust, Leaf rust	Relative Scale Rating (1-9)	Wheat Variety Guide Western Australia 2008 -2012;
Powdery mildew, Flag Smut	Relative Scale Rating (1-9)	Wheat Variety Guide Western Australia 2008 -2012;
Maturity	Short; Short-Mid; Mid; Mid-Long; Long	Wheat Variety Guide Western Australia 2008 -2012;
Classification	AH; APH;APW; ASW; ASWN; ASFT; AGP: Feed	Wheat Variety Guide Western Australia 2008 -2012;Grain Trade Australia, Section Wheat Standard 2012/2013 Season;
Free to Trade	Allow grower to grower trade;	Wheat Variety Guide Western Australia 2008 -2012;
Variety Owner	Owner of variety	National Variety Trail; Wheat Variety Guide Western Australia 2008 -2012;

Source: Author

4.5.4 Descriptive Statistics

Data used in this study comes from Western Australia and covers the years 1984-2011. To estimate the econometric model, the data is stacked and sorted by year and variety name in chronological order. The stacked dataset enables each variety to be observed according to the years since release. After the data is properly sorted and stacked, comparable estimates are established for all wheat variety information. Data configuration is needed for the independent parameters; yield ratio, disease resistance and quality enhancement.

The descriptive statistics of explanatory variables, except the dummy variables, are presented in the Table 4.2.

Table 4.2 Descriptive Statistics

Variable	Mean	Observation	Standard Deviation
Adoption	4.09	369	6.59
EPR rates	.87	369	1.15
Yield Ratio	.88	369	.11
*Deflated GVP *Yield Ratio*	257.77	369	59.93
Quality	5.2	369	1.77
Disease Resistant	4.51	369	.92
Time since release	10.31	369	9.07

Source: Author based on obtained data

The expected signs of determinants in the model are assessed based on economic theory.

Table 4.3 Expected Signs of Determinants

Descriptive variable	Expected sign	Reasoning
Yield Ratio	+	When yields increase, the percentage of adopted acres is expected to increase.
EPR rates	-	When price increase, the percentage of adopted acres is expected to decrease.
Time	+	Captures time trend of increasing percentage of acres adopted over time, adjust to its curvature.
Time Squared	-	Captures time trend of decreasing percentage of acres adopted over time adjust to its curvature.
Time Cubic	+	Captures time trend of increasing percentage of acres adopted over time adjust to its curvature
Quality	+	When Quality increase, the percentage of adopted acres is expected adoption
Disease resistance	+	As a disease resistance increases the percentage of adopted acres is expected to increase.
GVP * Yield Ratio	+	As price of output increase the expected percentage of adopted acres of high yielding varieties is expected to increase

Source: Author

4.6 Empirical Model

Determinants of the variety adoption in the econometric model, presented in equation 4.3 below, are chosen based on the above theoretical model, literature, previous econometrical studies, economic theory and availability of data. To capture the dynamics of variety adoption and reflect the product life cycle, time since release is introduced in the model as a variable T with its squared and cubic values. Squared and cubic values are incorporated to capture a whole life cycle of variety adoption (including variety growth, stage of maturity and decline in adoption).

$$\%Adoption_{it} = \beta_0 + \beta_1\,Yield\ Ratio_{it} + \beta_2\,End\ Point\ Royalty\ Rate_i + \beta_3\,Time\ since\ Release_{it} + \beta_4\,Time\ since\ Release_{it}^{2} + \beta_5\,Time\ since\ Release_{it}^{3} + \beta_6\,Variety\ Owner_{it} + \beta_7\,Maturity_{it} + \beta_8\,Plant\ Breeder\ Rights_{it} + \beta_9\,Gross\ Value\ of\ Production_t \text{ times } Yield\ Ratio_{it} + \beta_{10}\,Quality_{it} + \beta_{11}\,Disease\ Resistance_{it} + \beta_{12}\,Classification_{it} + \beta_{13}\,Free\ to\ Trade_{it} + \varepsilon \qquad \textbf{(4.3)}$$

where:

$\%Adoption_{it}$ = percent of adoption of i[th] variety in period t;
EPR_i= End Point Royalty rate of i[th] variety;
$Quality_i$ = quality of i[th] variety;
$Disease\ Resistance_i$ = disease resistance of i[th] variety;
$Maturity_i$ = maturity of i[th] variety(set of dummy variables);;
$Classification_i$ = classification of i[th] variety(set of dummy variables);;
$Variety\ owner_i$= variety owner of i[th] variety (set of dummy variables);
$Time\ since\ release_{it}$ = number of years since i[th] variety release;
$Time\ since\ release_{it}^2$ = number of years square since i[th] variety release;
$Time\ since\ release_{it}^3$ =number of years cubic since i[th] variety release;
GVP_t = Gross Value of Production in period t, used as instrument for wheat price;
$Yield\ Ratio_{it}$ = yield ratio (yield of i[th] variety/ yield of next best alternative);

To estimate the econometric model with shares of each variety in total area seeded by wheat varieties as a dependent variable, data are pooled across varieties (i) and time (a year)(t).

The Fixed effect model was not chosen because this approach would rule out the estimation of EPR rates impact on variety choice, as EPR Rates are fixed over time for each variety and would be perfectly collinear with the fixed effect. After the data is organized, an OLS regression model is estimated in the statistical software STATA.

Testing and Interpreting the Regression Outputs

The regression output is produced and examined. The first step to obtain an appropriate model to predict wheat variety lifecycles is estimation of the full model with all explanatory variables presented by equation 4.3 and estimation results presented in Table 4.5 in the first column.

Heteroskedasticity

The model is estimated using robust standard errors. The homogeneity of variance of the residuals is one of the fundamental assumptions for the ordinary least squares regression. A well-fitted model should not have a pattern to the residuals plotted against the fitted values, its variance should be constant. If the variance of the residuals is non-constant then the residual variance is called heteroskedastic.

If heteroskedasticity is present parameter estimates are not biased but OLS estimates are not "best linear unbiased estimates". Specifically, among all the unbiased estimators, OLS does not offer the estimate with the smallest variance. In addition, depending on the nature of the heteroskedasticity, significance tests based on OLS estimated standard errors can be too high or too low (Berry and Feldman 1985). All models were tested and suffered from heteroskedasticity.

I chose OLS with robust standard errors as the method to address heteroskedasicity. When heteroskedasticity is present, robust standard errors are likely to be more accurate and provide more reliable test statistics. A limitation of this approach is usage of robust standard errors does not affect the estimate of coefficients, or directly improve the efficiency of the OLS estimates. Higher efficiency could be achieved with Weighted Least Squares (WLS). However, WLS requires knowledge of what observational weights to use and applying incorrect weights can decrease efficiency relative to OLS. Given the lack of knowledge about correct weights, OLS with robust standard errors was chosen to estimate the model, which is a common method of dealing with heteroskedasticity.

The Adjusted Model

The Full model was reduced as needed to uncover the appropriate model for predicting wheat variety lifecycles. The full model was tested for collinearity and test results are reported in Appendix B.

Collinearity

Collinearity statistics, with the tolerance level and the variance inflation factors (VIF) were examined and used as criteria for exclusion. As a rule of thumb, a variable with VIF values larger than 10 may be worthy of further examination. To check the degree of collinearity researchers typically use the tolerance, defined as 1/VIF. The tolerance value below 0.1 is analogous to a VIF of 10 and greater. The variable with tolerance value less than 0.1 could be viewed as a linear combination of other independent variables.

All variables, which had a VIF greater than 10, other than time since release variables in the Full model, were dropped and the model was again tested for collinearity. Also insignificant variables, which when removed from the model increased the adjusted R squared, were removed. The adjusted model chosen as the best suitable econometric model to predict Western Australia wheat varieties lifecycles is expressed by equation 4.4 and reported in the third column of Table 4.5.

$$\%Adoption_{it} = \beta_0 + \beta_1\, Yield\ Ratio_{it} + \beta_2\, End\ Point\ Royalty\ Rate_i + \beta_3\, Time\ since\ Release_{it} + \beta_4\, Time\ since\ Release_{it}^{2} + \beta_5\, Time\ since\ Release_{it}^{3} + \beta_6\, Variety\ Owner_{it} + \beta_7\, Maturity_{it} + \beta_8\, Gross\ Value\ of\ Production_t \text{ times } Yield\ Ratio_{it} + \beta_9\, Quality_{it} + \beta_{10}\, Disease\ Resistance_{it} + \beta_{11}\, Classification_{it} + \varepsilon_{it} \quad \textbf{(4.4)}$$

The VIF collinearity test for the variables included in Appropriate Prediction Model are computed and presented in Table 4.4.

Table 4.4 Collinearity Test - Adjusted Model

Variable	VIF	1/VIF
$(Time)^2$	**286.94**	**0.00**
$(Time)^3$	**107.69**	**0.01**
Time	**59.26**	**0.02**
Yield Ratio	9.22	0.11
Owner 2	5.95	0.17
Mature 1	4.29	0.23
Mature 2	3.49	0.29
Class6	3.18	0.31
Disease Resistance	3.13	0.32
Mature 4	3.05	0.33
EPR	2.96	0.34
Class 8	2.41	0.41
Owner 13	2.26	0.44
Quality	2.10	0.48
Class3	2.06	0.49
Mature 3	2.03	0.49
Owner 1	1.64	0.61
Owner 11	1.62	0.62
Deflated GVP *yield ratio	1.43	0.70

Source: Author

As can be observed in the Table 4.4 there is collinearity between time squared and time cubic, however, existence of those variables in the model is justified by the fact that they enable capturing the lifecycle of varieties adoption.

The Full model is displayed in the first column of Table 4.5 and produces results where few of the explanatory variables are found to be significant, and a number of explanatory variables were found to be not significant. The Number of observations in the Full model is 259. R squared of the model is 0.5151 and Adjusted R squared is 0.4630.

The estimates of the Adjusted Model are displayed in Table 4.5 column 2. Many explanatory variables are statistically significant in this model. Also, adjusted R squared 0.498 in this model is greater than adjusted R squared in the full model 0.463. The adjusted model produced an F-statistic value of 18.84 making the overall model significant.

Table 4.5 OLS Estimates of the Model

%Adoption	(1) Full Model All Inclusive Model Robust Std Errors	(2) Adjusted Model Appropriate Prediction Model Robust Std Errors
PBR	2.69 (2.22)	-
EPR Rates	-.97 (.64)	-.59* (.29)
Free to trade	-.79 (1.02)	-
Yield Ratio	50.35** (11.66)	34.73** (7.84)
Quality	.74* (.30)	.51* (.26)
Disease Resistance	-1.03 (.80)	-.51 (.44)
Time since Release	2.299** (.34)	1.4849** (.20)
$(\text{Time since Release})^2$	-.1488** (.03)	-.06569** (.01)
$(\text{Time since Release})^3$	.002588** (.0007)	.0007093** (.0002)
GVP*YieldRatio	.0018 (.006)	.005 (.005)
Owner1 (AGT)	-6.02** (1.74)	-3.54** (1.10)
Owner 2 (DAFWA)	8.16* (3.39)	5.87** (1.54)
Owner 6 (InterGrain)	-2.66 (1.63)	-
Owner 7 (LongReach)	-.85 (1.90)	-
Owner 11 (QDPI)	-6.38** (1.73)	-5.25** (.82)
Owner 12 (SA RDI)	-2.63 (2.16)	-
Owner 13 (University of Adelaide)	-7.40* (2.84)	8.64** (1.13)
Owner 15 (VDPI)	-7.99 (2.69)	-
Class 3 (AH)	-2.33 (1.25)	-4.34** (.97)
Class 6 (ASFT)	-8.39** (1.74)	-11.56** (1.56)
Class 8(ASWN)	-1.70 (1.47)	-4.50** (1.40)
Mature 1(Long)	-2.11 (1.74)	-1.39 (1.37)
Mature 2(Mid)	-.99 (1.30)	-.58 (1.29)
Mature 3(Mid-Long)	-.52 (2.40)	-7.73** (1.83)
Mature 4 (Short)	-4.24* (1.73)	-4.65** (1.74)
Constant	-43.23** (12.83)	-29.33** (9.15)
Observations	259	369
R- squared	0.52	0.52
Adjusted R-squared	0.46	0.50

Source: Author; Note: Robust standard errors in parentheses * significant at 5% level; ** significant at 1% level

In order to analyze separately how individual explanatory variables affect *Adoption, Adoption* was regressed on *Time since Release* and its *squared* and *cubic* values. As presented in the first column of Table 4.6 *Time since Release* and its *squared* and *cubic* values are found to have a statistically significant impact on variety adoption but the model has very low R square at 4%. Then, *Adoption* was regressed on *Time since Release* variables and *Yield Ratio, deflated GVP* interacted with *Yield Ratio*, as well as *Quality* and *Disease Resistance.* All variables except *deflated GVP* interacted with *Yield Ratio* and are found to have a statistically significant impact on variety adoption. Adjusted R Squared increased from 5% to 17%. In the third column *EPR Rates* are added to the model. *EPR Rates* are found to be statistically not significant however Adjusted R squared increased to 18%. Finally the fourth column represents the model chosen as an appropriate model to predict wheat variety lifecycles.

Table 4.6 OLS Estimates of Submodels

%Adoption	(1) Adoption Regressed on Time with Robust ST Errors	(2) Adding Regressors Yield Ratio, GVP interacted with Yield Ratio, Disease Resistance and Quality	(3) Adding Regressor EPR rates	(4) Appropriate Prediction model with Robust St Errors
Time since Release	.754**	1.361**	1.300**	1.4849**
	(.10)	(.17)	(.20)	(.19)
$(\text{Time since Release})^2$	-.043**	-.0706**	-.0681**	-.06569**
	(.008)	(.01)	(.01)	(.01)
$(\text{Time since Release})^3$	.000636**	-.0010**	.0010**	.0007093**
	(.0001)	(.0002)	(.0002)	(.0002)
Yield Ratio	-	11.019**	11.62**	34.73**
		(3.99)	(3.92)	(7.84)
GVP*YieldRatio	-	.009	.008	.005
		(.005)	(.006)	(.005)
Disease Resistance	-	-.979**	-.93**	-.51
		(.22)	(.23)	(.44)
Quality		.657**	.644**	.51*
		(.13)	(.13)	(.26)
EPR Rates	-	-	-.25	-.59*
			(.29)	(.29)
Owner 1(AGT)	-	-	-	-3.54**
				(1.10)
Owner 2 (DAFWA)	-	-	-	5.87**
				(1.54)
Owner 11 (QDPI)	-	-	-	-5.25**
				(.82)
Owner 13 (University of Adelaide)	-	-	-	8.64**
				(1.13)
Class 3 (AH)	-	-	-	-4.34**
				(.97)
Class 6 (ASFT)	-	-	-	-11.56**
				(1.56)
Class 8(ASWN)	-	-	-	-3.93**
				(1.56)
Mature 1(Long)	-	-	-	-2.06
				(1.07)
Mature 2(Mid)	-	-	-	-1.40
				(.93
Mature 3(Mid-Long)	-	-	-	-7.92**
				(1.30)
Mature 4 (Short)	-	-	-	-5.58**
				(1.17)
Constant	-.47*	-12.84**	-12.74**	-23.26**
	(.23)	(4.46)	(4.50)	(7.86)
Observations	1085	491	491	369
R- squared	0.05	0.1788	0.18	0.51
Adjusted R-squared	0.04	0.17	0.17	0.49

Source: Author

Note: Robust standard errors in parentheses * significant at 5% level; ** significant at 1% level

4.7 Discussion of the Results

The second column in Table 4.5 and last (fourth) column in Table 4.6 represent adjusted model estimation results with robust standard errors. The explanatory variables included in the model are statistically significant except for Disease Resistance; GVP interacted with Yield Ratio and two dummy variables for maturity. The model includes 369 observations. The adjusted R-Squared value for estimation of this adjusted model is 0.4983, concluding a reasonable goodness of fit where approximately 50.0% percent of the variation in percentage of area of each variety can be explained by the variation of the independent variables in the model.

Yield Ratio

The coefficient of yield ratio is statistically significant at 1% significance level and has sizable t-statistics. The sign of the coefficient is positive and suggests the yield and adoption rate are positively correlated. If yield ratio increases by 0.1 the adoption is expected to increase by 3.47 percent, holding all the other variables constant.

Economic theory suggests farmers increase the percentage of adoption if the variety has a higher yield potential. Varieties with higher yield are favoured over the leading competitors since varieties with increasing yield ratios increase the potential to maximize profits. Farmers will adopt a variety with the highest yield potential in an attempt to maximize profits.

EPR Rates

The coefficient of EPR Rates is significant at 5% significance level. The sign of coefficient is negative as expected and suggested by economic theory. An estimation result shows that if EPR rates increase by one dollar per tonne the market share of variety expressed as a percentage of total area seeded to wheat decreases by .59 percent of total area seeded by wheat, holding everything else constant. The implied price elasticity of demand is discussed in Section 4.7.3.

Quality

The coefficient of Quality is significant at a 5% significance level. The sign of coefficient is positive as expected and suggests that quality and adoption are positively correlated. If quality increases by one unit the expected adoption is going to increase by .51, holding everything else constant.

It is not a surprising result that higher quality creates higher potential for profit and therefore attracts farmers to pick high quality varieties.

Disease Resistance

The coefficient of Disease Resistance is statistically not significant.

Variety Owner

The model was initially specified with HRZ Wheats excluded. Furthermore, based on collinearity and goodness of fit criteria owners such as InterGrain, EGA, Victoria DPI, SA DPI, NSW DPI, NSW I&I, Nuseed or GBA were also dropped from the model. Four dummy variables for variety owner, representing: DAFWA, University of Adelaide, QDPI and AGT have been found to be statistically significant explanatory variables in the model. Dummy variables for DAFWA and University of Adelaide have positive signs, dummy variable for QDPI and AGT have a negative sign suggesting varieties owned by DAFWA and University of Adelaide are more likely to be adopted, whereas varieties owned by QDPI and AGT are less likely to be adopted relatively to varieties owned by institutions represented by dropped from the model dummy variables.

Farmers in Western Australia tend to adopt varieties developed by DAFWA. DAFWA for many years has been developing varieties specifically for Western Australia; therefore, DAFWA's varieties are well recognized and well matched to the needs of the Western Australia climate and soil type. QDPI is placed in Queensland, a small state located far from Western Australia, and is a relatively new contributor that may be seen as dissimilar to Western Australia. Negative sign of AGT may be caused by being the biggest competitor for WA based InterGrain.

University of Adelaide and AGT are both located in Adelaide far from WA and have opposite impact on variety adoption that may be caused by change from public to private ownership of wheat breeding or the fact that University of Adelaide is much older than InterGrain. Also when wheat breeding was done by public sector competition between variety owners was not playing such a role as after privatization of wheat breeding. With private ownership farmers exhibit more loyal behaviour towards locally developed varieties.

Classification

Three dummy variables for classifications including Australian Hard, Australian Standard White Noodle and Australian Soft were found to be negative and statistically different than zero at a 1% of significance level. These effects on adoption suggesting that, *ceteris paribus,* those types of wheat are less popular than the Australian General Purpose Class (originally omitted) and Australian Premium Hard, Australian Standard White, Australian Premium White and Feed (which were dropped from the model based on their lack of explanatory power) among Australian farmers. This result is not surprising given the typically lower prices for Australian Hard, Australian Standard White Noodle and Australian Soft wheat varieties.

Maturity

Two dummy variables for maturity, Mid-Long and Short have been found to be negative and statistically different than zero at a 1% of significance level. This implies these categories in time to maturity have a negative impact on variety adoption relative to the Short–Mid which was originally omitted and Long maturity, and Mid maturity, which were subsequently dropped from the model based on their lack of explanatory power. This pattern of preference has no obvious explanation. Farmers do not adopt varieties with a short term to maturity because Western Australia climate is suitable for varieties with long term maturity. This however, does not explain why mid long is less preferred to both Long and Mid maturity.

Time Since Release

Time since variety release (measured in years) is introduced to the regression so as to estimate varietal lifecycles. The variables of *time since variety released*, *time since variety* *released squared* and *time since variety released cubed* produce respectively positive, negative and positive signs, as expected. All three coefficients are significant at the 1% of significance level.

Figure 4.3 displays the impact of years since release on adoption using the time since release coefficients from Table 4.5. The impact of time on adoption is positive and follows classical adoption and dis-adoption lifecycle trends. The largest positive impact on adoption is at about 9.89% of market share and is reached 15 years after the variety was released. Based on the estimated coefficient time has a net positive impact on adoption for about 39 years. Therefore, wheat varieties follow product lifecycle trends as indicated in the literature.

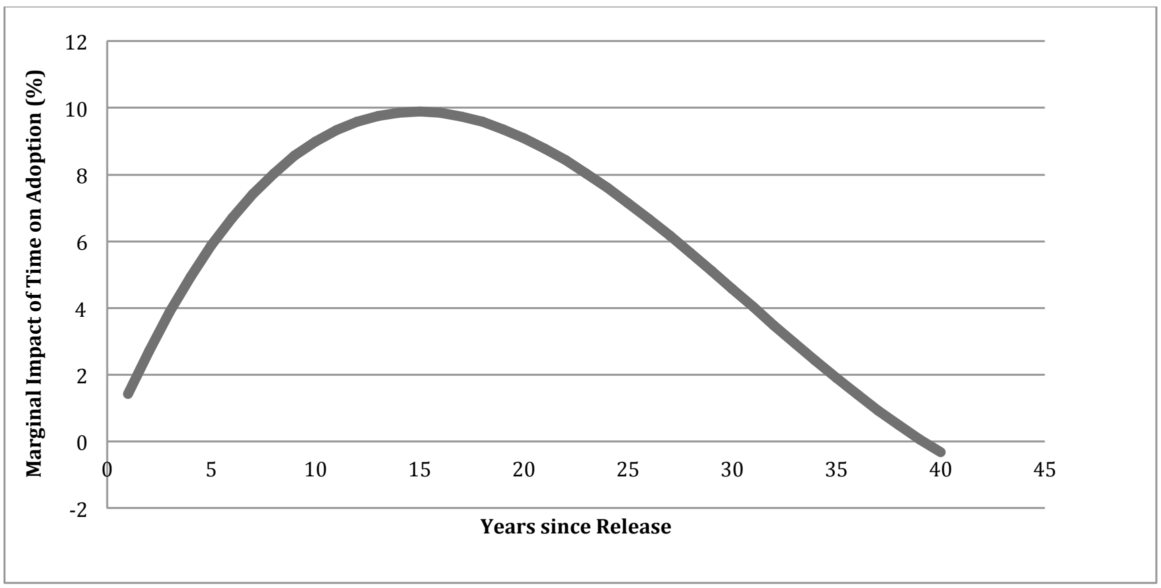


Figure 4.3 Time Trend for Wheat Variety Adoption in Western Australia.

Source: As calculated by Author

Product lifecycle curve relates to S shaped adoption curve. Initially low adoption level increase over time as more people chose to adopt variety. Variety adoption reach top and move to disadoption stage of product lifecycle, which S shaped adoption curve do not capture.

4.7.1 Product Life Cycles - Average Adoption Model

The estimates of prediction model are presented in column 4 of Table 4.5 and can be used to predict a variety lifecycle based on variety characteristics. The model was established to estimate the percentage of acres adopted by particular wheat varieties in Western Australia based on information provided for each variety.

Using the mean values for variables in the model and estimated parameters the average product lifecycle was predicted. The average predicted lifecycle produced by estimation result is presented on Figure 4.4 below. The predicted average lifecycle is for varieties being released by a breeding company different than AGT, DAFWA, University of Adelaide or QDPI. Also, the average variety is not being classified as Australian Hard, Australian Standard White Noodle or Australian Soft. The time to maturity for the predicted average variety is not Short or Mid-Long.

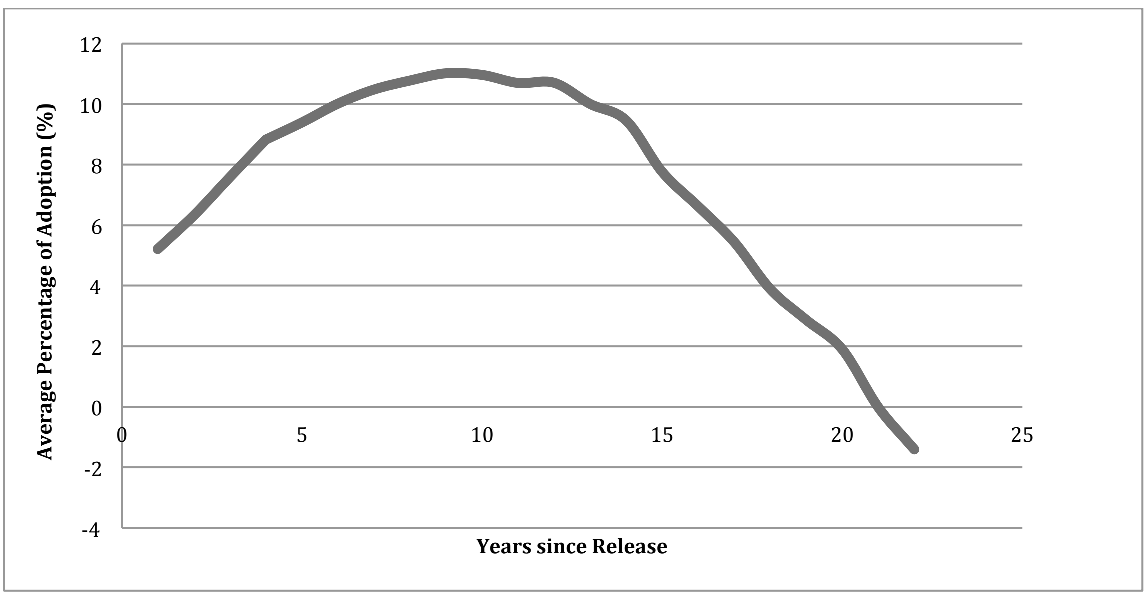


Figure 4.4 Predicted Average Lifecycles.

Source: As calculated by Author

As can be observed in Figure 4.4, the predicted average adoption model for wheat varieties adopted in Western Australia follows a standard life cycle model. Top of adoption reaches 11.02 % of market share and is obtained in about 9 years after variety release. The variety stays in the market for about 20 years.

In comparing the predicted average lifecycle to time trend it can be observed that explanatory variables in the model speed up adoption and increase adoption levels relative to time trend. For varieties with short and mid- long time to maturity, as well as classified as Australian Hard, Australian Soft and Australian Standard White Noodle or released by QDPI or AGT, the average predicted lifecycle would be characterized by a lower adoption rate. Varieties released by DAFWA or University of Adelaide would have higher adoption rates.

4.7.2 The Impact of EPR Rates on Variety Adoption

The focus of this Chapter was to estimate the impact of EPR rates on wheat variety adoption. As stated above, the estimated impact is statistically significant at 1% of significance level and as expected, causes adoption to decrease. The EPR coefficient is equal to –.59, and can be interpreted as follows: If the EPR rate of a variety increases by one dollar per tonne, market share of that variety decreases by .59 percent of total area seeded to wheat, all other variables held constant. The one dollar increase in EPR rates constitutes a large percentage increase in EPR rate since average EPR rate is .87 \$/tonne and the highest EPR rates are 3.5 \$/tonne. On the other hand a decrease by .59 percentage points of market share constitutes a much smaller proportional decrease in market share, which average 4.1% market share over the data. Given the average EPR rate of .87 \$/t and the 4.1% adoption percentage, the elasticity of demand for a variety at the mean of the data set is:

$$\text{Elasticity } = A\%'(EPR)\frac{EPR}{A\%} \quad (4.5)$$

$$\text{Elasticity } = -.59\frac{EPR}{A\%} = -.59\frac{.87}{4.09} = -.13. \quad (4.6)$$

This is a very price inelastic demand. This suggests that breeding companies could raise EPR rates for wheat varieties without really compromising peak adoption rates. The price elasticity of average predicted adoption at the highest point of its adoption, which is 11%, would be

$$\text{Elasticity } = \frac{-\frac{.59}{11}}{\frac{1}{.87}} = -.05 \quad (4.8)$$

The own price elasticity of e.g. Wyalkatchem at the highest point of its adoption of 32.7 % would be

$$\text{Elasticity } = \frac{-\frac{.59}{32.7}}{\frac{1}{1.92}} = -.03 \qquad (4.9)$$

The own price elasticity in absolute value in all three cases is significantly less than one. The higher the market share of variety, the more inelastic is the demand. The inelastic demand suggests market power of breeding companies would bring EPR rates to a very high level. Obtained results seem to confirm expectations developed in previous chapters that Australian EPR rates will grow much larger unless public and producer ownership of wheat breeding companies will prevent significant growth of EPR rates.

Knowing how demands for wheat varieties respond to change in EPR rate, the next Chapter analyzes how uniform EPR pricing would affect adoption of varieties and welfare in the Australian wheat market.

4.8 Chapter Summary

The objective of this Chapter was to choose and estimate a model that fits wheat varieties adoption patterns and estimates impact of EPR rates on variety adoption. Based on existing literature, the lifecycle adoption model similar to Dahl et al. (1999) was chosen as the most suitable model. Using wheat variety adoption data from the state of Western Australia, an adoption model for wheat varieties has been estimated. The adjusted model was chosen as the best predicting model with many of the potential explanatory variables found to be statistically significant and the model as a whole was statistically significant with adjusted R squared 49.83%.

Using estimation results, a predicted average adoption model was simulated and suggests that adoption of wheat varieties in Western Australia follows a standard product lifecycle. The top of adoption in average predicted adoption is achieved in about 9 years after variety release and reaches approximately 11.02 % of market share. An average variety stays in the market for about 20 years. The marginal effect of time on variety adoption was also simulated. The top of adoption, based only on time trend, is obtained in about 15 years of variety existence in the market and reaches approximately 9.89 % of market share. Consequently, on average, using estimated results, explanatory variables in the model speed up and increase adoption patterns relative to a pure time trend pattern.

The EPR rates, a focus of attention of this Chapter, were found to have a negative, statistically significant at 5% of significance level impact on variety's adoption. The estimated coefficient suggests that an increase in EPR rates by one dollar per tonne cause market share of the variety expressed as a percentage of total area of wheat to decrease by .59 percent of total area. This estimation result suggests price inelastic demand for an average variety with elasticity of – 0.13. For average variety the price elasticity at the top of adoption (predicted by the model) is equal to -0.05. The price inelastic demand suggests that breeding companies have market power to significantly increase EPR rates without compromising much demand for variety. Inelastic demand hints that a switch to a uniform EPR system should not significantly affect variety choice.

Having empirical estimates of how demand for varieties responds to change in EPR rates, the next Chapter will analyze the impact of switching to uniform EPR rates on variety adoption and economic surplus by simulating adoption curves, average yield and revenue under uniform EPR rates system.

Chapter 5

THE IMPACT of UNIFORM EPR RATES on VARIETY ADOPTION and WELFARE in WESTERN AUSTRALIA

5.1 Introduction

As Canada is implementing UPOV 91 and planning to introduce its own EPR system, the impacts of EPR rates on wheat variety adoption, and on economic surplus becomes an important consideration. With that in mind, Chapter 5 uses the empirical model reported in Chapter 4 to simulate the adoption of Australian wheat varieties under a hypothetical counterfactual simulation of uniform EPR rates. This simulation enables comparison of both variety adoption rates and economic welfare impacts under uniform EPRs, currently used in France, to those observed under variable EPR rate systems employed in Australia.

5.1.1 French EPRs

The motivation to analyze uniform EPR rates comes from the French royalty collection system that employs a system of uniform across variety EPR rates across varieties. The French EPRs were established in July 2001 after an extended course of discussion among farmers, breeders and the government (Gray and Bolek 2011). The royalties are collected via an EPR known as Contribution Volontaire Obligatoire, (CVO), of value *0.70€,* (approximately *$1.10*), per tonne. The CVO is charged on the sale of all bread wheat at the time of delivery to a marketer. Once CVO is collected, "small farmers" who produce less than *90* tonnes can apply for a full rebate of the royalty. Farmers who bought certified seed can also apply and receive a refund of *20€,* (*$27.60*), per tonne of purchased seed. After these rebates are paid, *85%* of the money raised by the levy is submitted to a property rights management organization for plant breeders '*Groupement National Interprofessionnel des Semences et des plants' (GNIS)*. This organization works with *'Société Coopérative d'Intérêt Collectif Agricole anonyme des Sélectionneurs Obtenteurs,'* (SICASOV), to allocate the royalties to breeders in proportion to their varieties' individual shares of certified seed sales. The remaining *15%* of the money raised by the CVO is used to support public wheat research (Talvaz 2013).

The French royalty collection system has overcome a number of challenges inherent in the Australian system struggles with. Five inherent advantages of the French system would seem to be: 1) As the CVO applies to the sale of all wheat varieties it is relatively simpler to administer; 2) The uniform rate for all varieties eliminates any incentives for producers to mis-declare varieties as there is no price difference; 3) The uniform royalty rate speeds up the adoption of varieties with better characteristics by putting these varieties on an the same price level as all existing varieties; 4) Following the idea from the third point, the EPR rates achieve compensatory level even when prior varieties still exist in the market place; 5) Finally, since the EPR rate is negotiated between the seed industry and the farm leaders every three years, the system removes the risk that the concentrated industry will charge excessive royalty rates. These characteristics suggest the uniform EPR rates system could be an attractive option for an EPR system in countries such as Canada (Gray and Bolek 2011).

Despite the apparent advantages of negotiated uniform EPR rates, there are still some weaknesses. Primarily, with a uniform EPR system the individual owners do not have the power to set the rate for a particular variety. Under certain circumstances, this could diminish royalty revenue for particular varieties, especially the niche markets that are very sensitive to such a situation and may not get covered at all. Conversely, under the Australian model breeders of niche varieties with less area are able to charge more per tonne as demand would be more inelastic (Gray and Bolek 2011). While negotiated uniform EPR rates can prevent the inefficiency caused by excessive privately set royalty rates, if negotiated rates are too low, it could imply a smaller share of benefits to seed companies leading to suboptimal research investment.

In theory, the uniform EPR rate could be set through negotiation to induce the optimal overall revenue for investment. However, by definition the uniform EPRs cannot reflect the differences in demand for varieties through differential prices. Economic theory suggests the price differentials can either increase or decrease welfare, depending on demand parameters.

Thus, the impact of switching to uniform EPR rates is an empirical question, addressed in this Chapter.

5.1.2 Chapter Objective

The objective of this Chapter is to analyze the difference between implementation of uniform EPR rates and varying EPR rate systems on variety adoption and economic surplus. Using the estimated adoption model from Chapter 4, this Chapter develops a counterfactual simulation for wheat variety adoption with uniform EPR rates. Comparing the counterfactual outcomes to the factual outcomes, the economic impacts of a move to uniform EPRs are assessed.

To reduce the dimensions of the problem, the simulated uniform EPR rates are set at a level to be revenue neutral. In each year, the uniform EPR rates are set at a rate that generates the same royalty revenue as was historically collected in Western Australia using variable EPRs. For instance, in the 2004 year of the simulation, the uniform EPR is adjusted to generate 4.8 million AUD in revenue, which is approximately equal to the historic 2004 EPR revenue. Simulating revenue neutral EPRs avoids having to deal with assessing the impacts of an infinite number of possible revenue streams, investment levels, and future returns enabling sharper focus on the allocative effects of uniform versus variable EPR rates.

Even though the analysis is done specifically on Western Australian data, it does provide one empirical assessment of the welfare impacts of EPRs, using an estimated system of variety adoption where EPRs have existed historically. Given the limited global experience with EPRs this may be the only data set where this empirical exercise can be done. As such, it provides unique estimates of the welfare impacts.

5.1.3 Chapter Outline

This Chapter is organised in five sections. Section 5.2 discusses the theoretical welfare implications of varying and uniform EPR systems. Section 5.3 introduces the counterfactual scenario of uniform EPR rates and its impact on adoption. Section 5.4 discusses the empirical welfare implication of using a uniform EPR system in the Western Australian market. The Chapter ends with summary and concluding comments in Section 5.5.

5.2 The Theoretical Welfare Impacts and Other Economic Issues

Alston et al. (1996) sketched the general empirical procedures that can be used to calculate the distribution of economic benefits from innovation. Producers' surplus from innovation can be represented as the change in the area underneath the corresponding input demand curves and above the market price. Surplus of the breeding company is the change in their profit, represented by the area above the marginal cost curve and below the price in the market. Assuming the output market is competitive, and the key input to producers is seed, measuring the change in surplus in the seed market gives the same results as measuring the change in total surplus in the output market (Just and Hueth 1979; Schmalensee 1976; Moschini and Lapan 1997; Acquaye and Traxler 2005).

A search of the literature did not reveal any economic literature that specifically dealt with the welfare and demand impacts of differential versus uniform pricing across horizontally differentiated products produced by an oligopoly of independent firms. There is, however, a significant body of literature that deals with the welfare economics of price discrimination by a monopolist, when demand segments for a homogeneous product are separated and priced independently. Given this literature's proximity to the question of study in this Chapter, this is a useful point of departure.

In the economic literature, numerous researchers analyze price discrimination by a monopoly. Robinson (1933), Schmalensee (1981), Varian (1985), Shih et al. (1988) Layson, (1988), Schwartz, (1990), Malueg (1993), and Acquaye and Traxler (2005) claimed that under basic conditions, third degree price discrimination can lead to an increase in (static) social welfare only if total output increases relative to output supplied under one price. According to Robinson (1933) for price discrimination to lead to an increase in total output the "concavities" of the marginal revenue curves must differ between the markets. Varian (1996) claimed the total output and welfare would increase if there were niche markets that were not covered under single price and were addressed under lower price when a monopoly can price discriminate. Given the ambiguous theoretical effects, Acquaye and Traxler (2005) agreed with earlier studies that, "whether discrimination leads to an increase or decrease in social welfare is an empirical question" (p.128).

In the case of differentiated wheat varieties, profit-maximizing pricing by separate variety owners can lead to a range of prices. This Chapter looks at the implications of imposing a revenue neutral uniform price on economic welfare. As stated above, varying and uniform EPR systems have different welfare implications. To illustrate those differences consider the two varieties owned by two monopolistic owners, represented in Figure 5.1. The *Marginal Cost (MC)* that breeding companies face when producing additional seed is equal to *zero* for both companies.

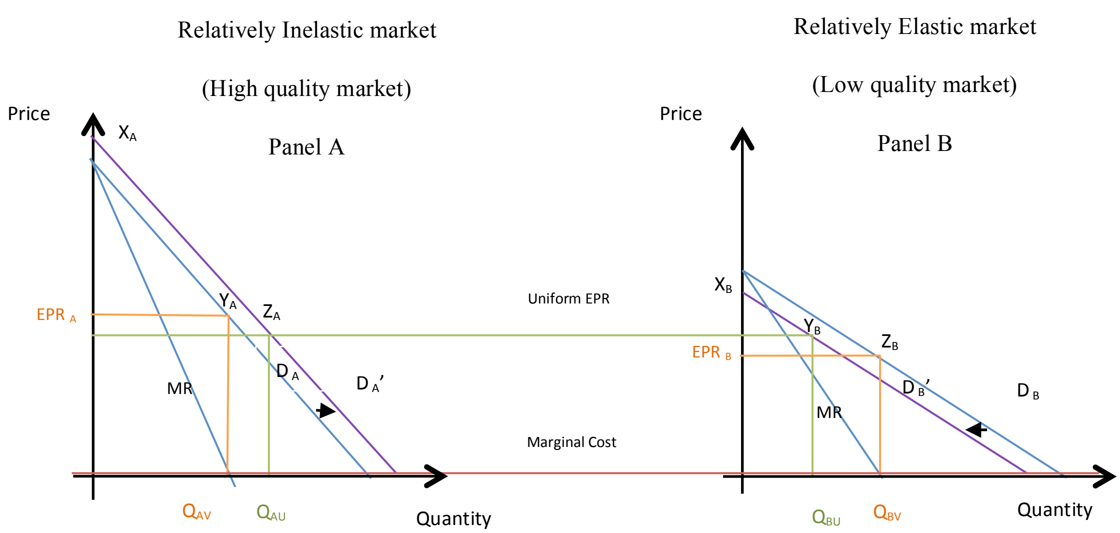


Figure 5.1 Differentiated Pricing for Two Wheat Varieties by Two Monopolistic Owners of Varieties IPRs, and the Uniform Pricing of Both Products.

Source: Author

The seed price (proxy for EPR rate) is obtained from standard monopolistic pricing behaviour. The demanded quantity is given by the point on the horizontal axis corresponding to *MR=MC*, and the EPR level is just responding to that quantity price on the demand curve. As illustrated in Figure 5.1 under a varying EPR rates system, (two monopolistic owners price their products separately from one another), the output in the high quality market is given by Q_{AV} with corresponding price EPR_A. In the low quality market, the output is given by Q_{BV} with corresponding price EPR_B. The triangle above EPR_A price and underneath demand curve for high quality variety D_A, (EPR_A, Y_A, X_A) represents farmers surplus in high quality markets with varying EPR rates. The triangle above EPR_B underneath the demand curve for low quality variety D_B, (EPR_B, Z_B, X_B) represents farmers' surplus in low quality markets with varying EPR rates.

Assuming there is a uniform EPR rate that preserves royalty income in the market; the uniform rate would be lower than the EPR rate charged for a high quality variety and higher than the EPR rate charged for a lower quality variety. If varieties are substitutes, then demand curves shift as a result of change in price of the substituting variety. The demand curve for the higher quality variety shifts out and the demand for the lower quality shifts in. The uniform EPR would increase adopted quantity of the higher quality variety and decrease the adopted quantity of the lower quality variety. In the market where uniform EPR rates are used, output in high quality market increases from Q_{AV} to Q_{AU}, while in low quality market output decreases from Q_{BV} to Q_{BU}. Farmers' surplus in high quality markets increase to ($EPR_{uniform}, Z_A, X_A$) and in low quality markets farmers' surplus decreases to ($EPR_{uniform}, Y_B, X_B$). The change in the surplus of breeding companies depends on the elasticity of demand in each of the markets and the magnitude of the demand shift. The breeder's profit in a high quality market decreases by the rectangle above *uniform EPR* and below varying EPR_A and increases by the rectangle between output levels corresponding to both EPR systems. A similar situation takes place in a low quality market where breeders' profit increases by the rectangle between uniform and varying EPR rates and decreases by the rectangle between output levels corresponding to both EPR systems. In both cases the net effect on revenue is ambiguous.

In summary, economic theory suggests that the effect of price discrimination on social welfare is ambiguous, suggesting that the impact is determined by market conditions, which by necessity, requires empirical study. The next section describes the construction of the counterfactual scenario of wheat adoption with a uniform EPR system developed to undertake this work.

5.3 The Counterfactual Wheat Adoption with Uniform EPR Rates

The counterfactual scenario of wheat adoption is created using the econometric adoption model estimated in Chapter 4 and data from Western Australia. As described in more detail below, the counterfactual simulation begins with the observed adoption curve for each wheat variety between 1999 and 2011 in Western Australia. For the counterfactuals, these "observed" or "factual" adoption curves are adjusted to reflect the uniform EPR rate structure in each year, using the estimated EPR coefficient multiplied by the difference between the observed EPR rate for each variety and the counterfactual uniform EPR rate for each year. After some calibration and adjustment for negative and missing values, the counterfactual adoption curves are compared to assess the adoption and welfare impacts of the move to uniform EPR rates.

As reported in Chapter 4, the EPR rate charged for a wheat variety has a negative impact on adoption. The estimated coefficient of EPR rates' impact on wheat variety adoption expressed as a percentage of total area seeded by wheat is -0.59, indicating a $1 increase in EPR rate per tonne reduces adoption by 0.59% of total area seeded by wheat. This coefficient is used to adjust the adoption pattern for each variety in each year under the counterfactual scenario of uniform EPRs. More specifically:

$$\%A_{it} - \%A_{it}^{U} = \Delta\%A_{it} = -.59 \cdot (EPR_i - \overline{EPR_t}), \tag{5.1}$$

where:

$\%A_{it}$= observed percent adoption of variety *i* in year *t*

$\%A_{it}^{U}$= percent adoption of variety *i* in year *t* with counterfactual uniform EPR

ΔA_{it} = Change in adoption of Variety i in year t

EPR_i =Observed EPR rate for variety *i*, and

$\overline{EPR_t}$ = the calculated uniform EPR rate in year *t.*

As mentioned in the introduction, to avoid any additional economic effects from changing the amount of revenue collected, in each year, the uniform EPR rates are set to a level where total revenue for variety owners in the market as a whole is relatively unchanged compared to what was observed in that year. Finding the exact level of uniform EPR rate to be revenue neutral required an iterative process. The uniform EPR rates were initially set at weighted average of EPR rates from Western Australia, for each year of the simulation. The wheat variety adoption curves were then shifted using the uniform EPR rate, adjusted to only non-negative values, and then weighted to sum to 100 per cent per year. Revenues were then recalculated for each year. If uniform EPR revenue was found higher (lower) than observed, then the annual uniform rates, $\overline{EPR_t}$ were proportionately adjusted downward (upward) to match revenue per year and the adoption and revenue was recalculated. This iterative process was repeated until revenue per year with uniform EPR rates and related adoption were approximately equal to total revenue per year under original adoption with varying EPR rates or:

$$Weighted\ Average\ EPR_i * Total\ Wheat\ Production_t = \overline{EPR}_t * (Total\ Wheat\ Production_t + Percentage\ Increase\ in\ Weighted\ Average\ Yield_t * Total\ \ Wheat\ Production_t) +/- \varepsilon. \quad (5.2)$$

where

$\overline{\text{EPR}}_t =$ uniform EPR rate in year t.

The percentage increase in weighted average yield is defined in section 5.4.1.

The uniform EPR rates used are presented in Figure 5.2.

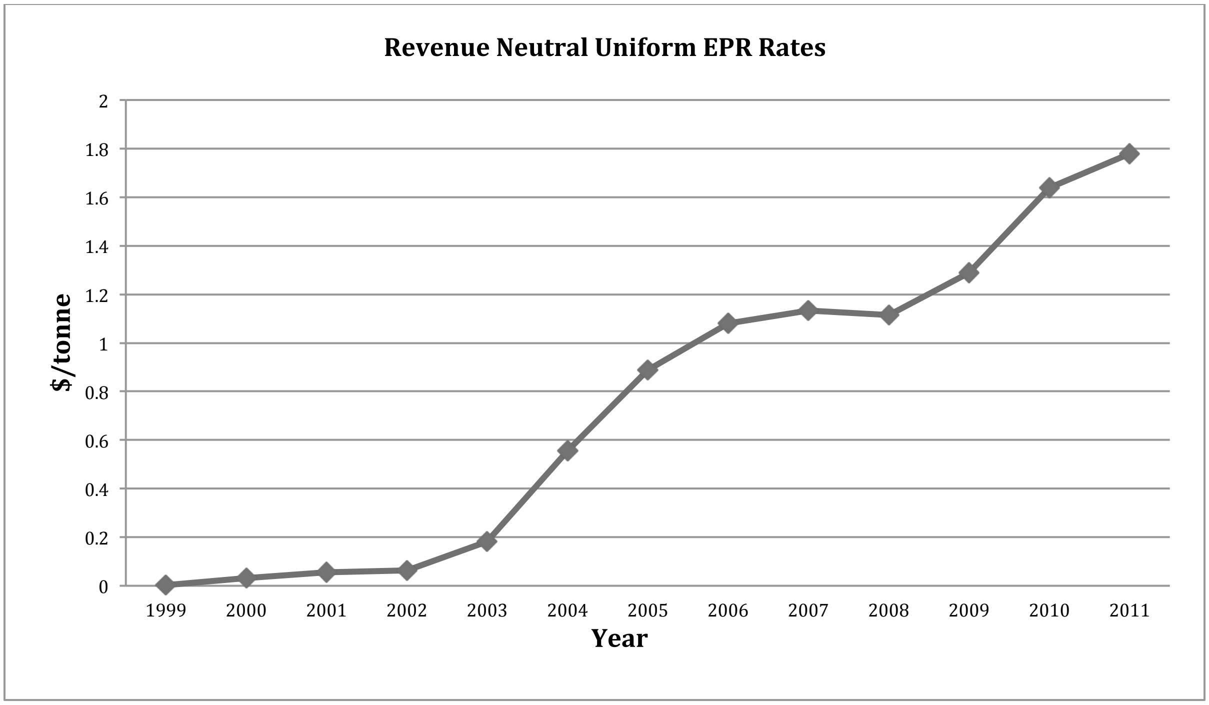


Figure 5.2 Revenue Neutral Uniform EPR Rates

Source: As calculated by Author

In the counterfactual, adoption curves are shifted using uniform EPR rates. The adoption of every variety was slightly different in the counterfactual scenario with uniform EPR rates than actual adoption. To illustrate impacts of change to uniform EPR rates, the average adoption for varieties with EPR rates attached to them and average adoption of those varieties under uniform system are presented in Figure 5.3 below.

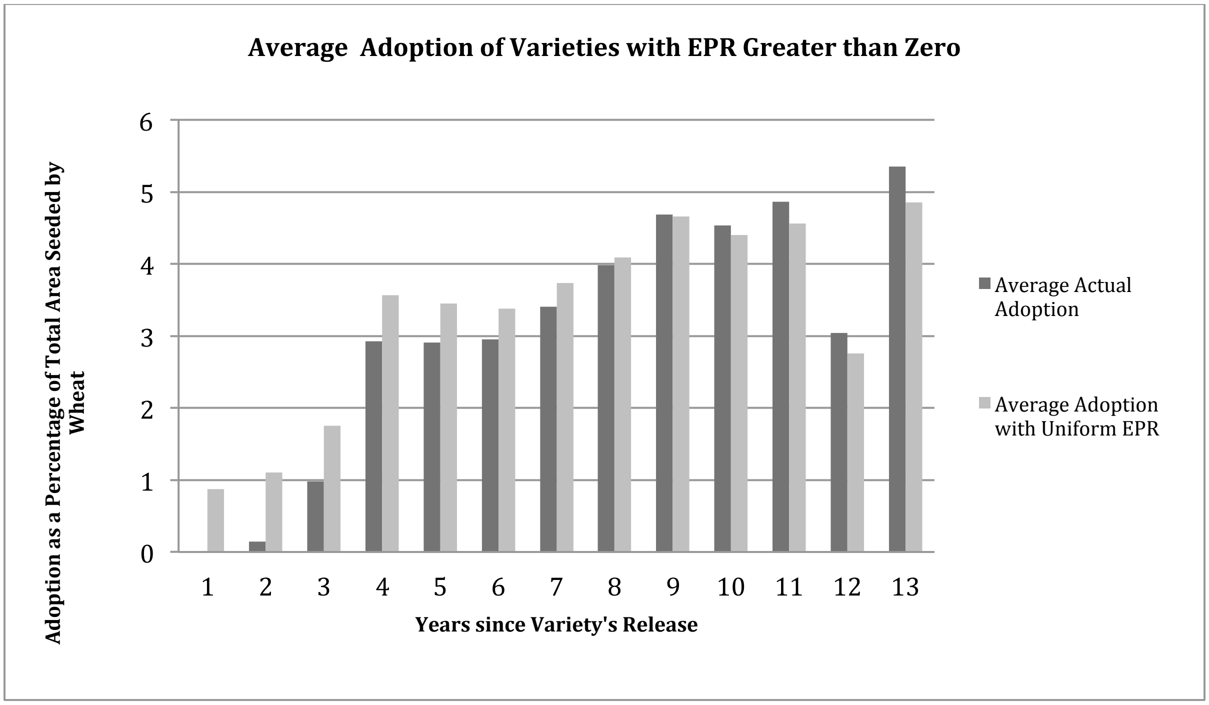


Figure 5.3 Average Observed Adoption Curve versus Average Adoption Curve with Uniform EPR rates for Wheat Varieties, with EPR Greater than Zero

Source: As calculated by Author

To analyze the change in average adoption, the difference in average adoption between adoption under the uniform EPR rate system and actual adoption is computed and presented in Figure 5.4.

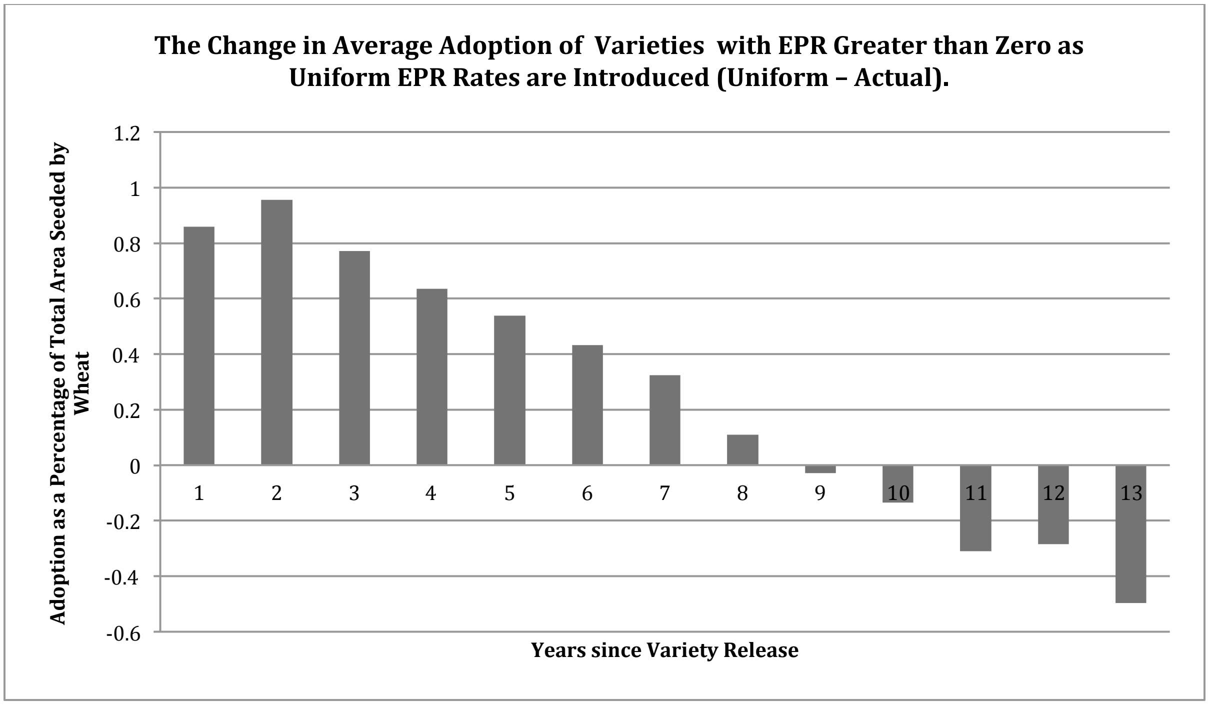


Figure 5.4 The Change in Average Adoption of Not Free Varieties as Uniform EPR Rates are Introduced (Uniform – Actual).

Source: As calculated by Author

As can be observed in Figure 5.4, the average wheat variety with non-zero EPR rates, "not free" wheat varieties adopted in Western Australia tend to be adopted and dis-adopted sooner when uniform EPR rates replaced varying EPR rates. This occurs because the higher EPR rates that typically deter the adoption of newer, better varieties, no longer exist under uniform EPR rates. With equal variety pricing, farmers have an incentive to choose newer, better varieties sooner, once they become available. Under uniform EPR rates, dis-adoption of varieties also occurs faster than under varying EPR rates. That result is also consistent with expectations. Because farmers have an incentive to adopt newer varieties sooner, they must also dis-adopt older varieties sooner.

As can be observed in Figure 5.4, the change to a uniform EPR rates system has a small in magnitude impact on average adoption, what has been expected as demand for varieties tend to be price inelastic and EPR rates are low.

The adoption of average free variety under actual scenario and counterfactual scenario with uniform EPR rates is presented in Figure 5.5.

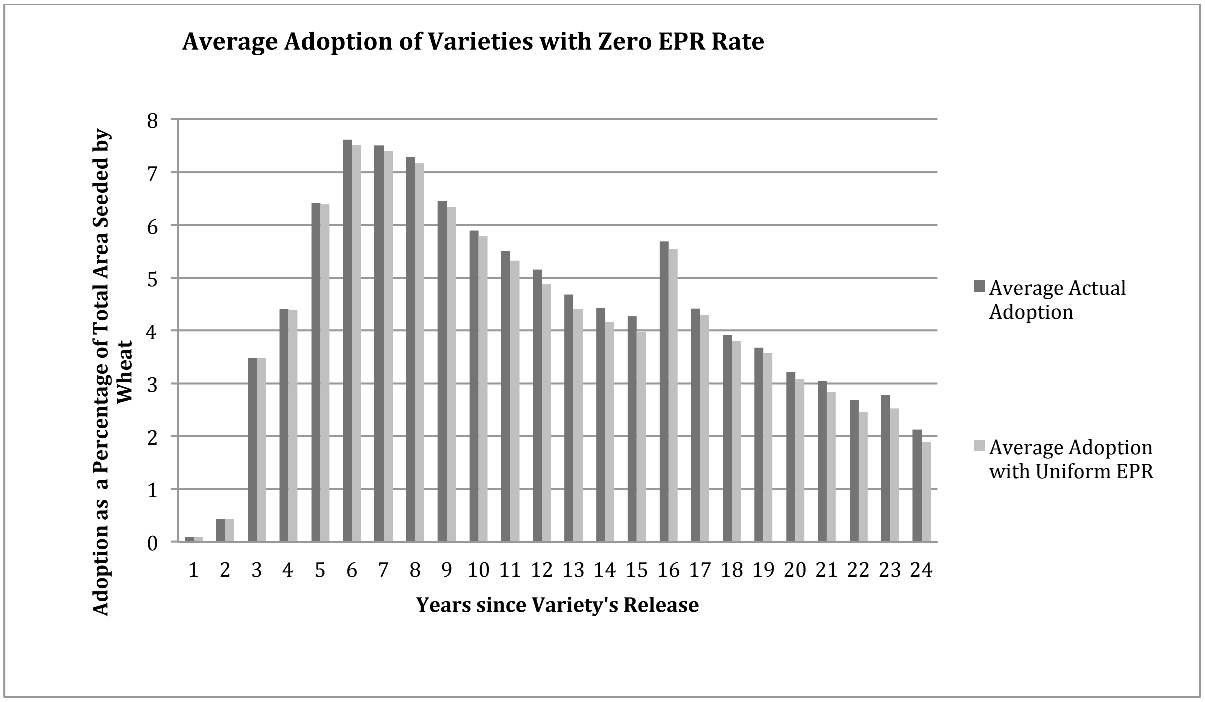


Figure 5.5 Average Adoption and Average Adoption with Uniform EPR rates of Wheat Varieties with Zero EPR

Source: As calculated by Author

The change in average adoption of free varieties as uniform EPR rates are charged is computed and presented in Figure 5.6.

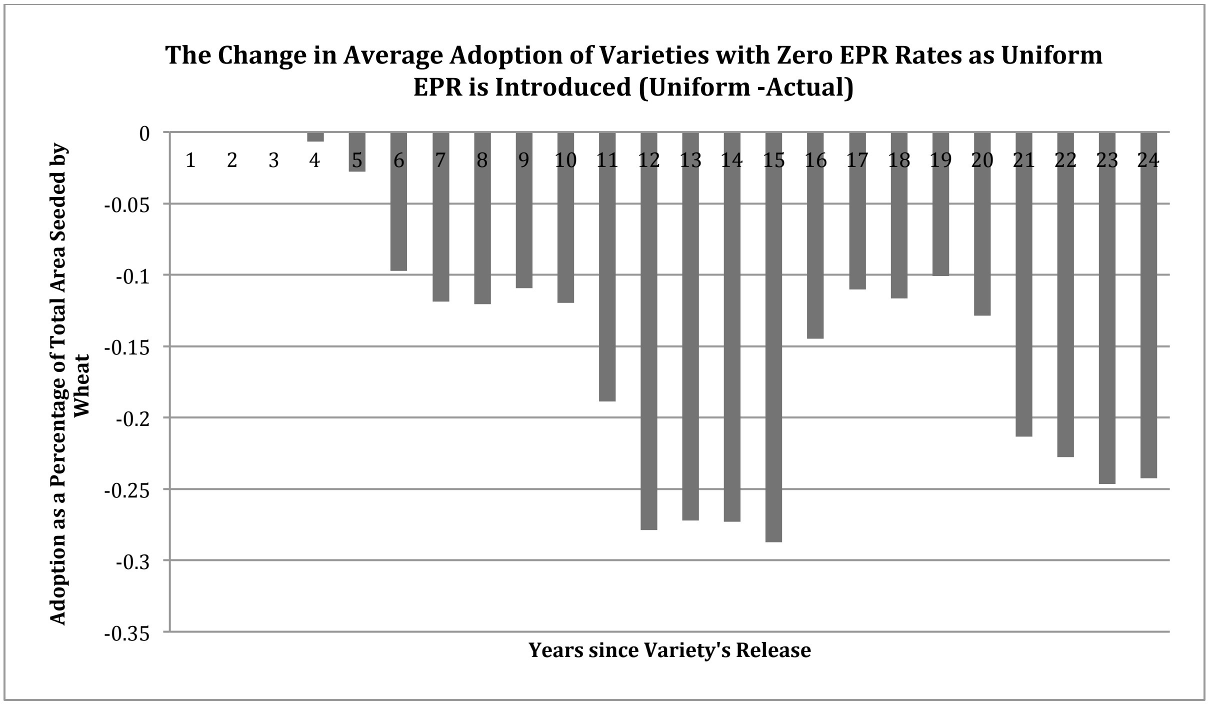


Figure 5.6 The Change in Average Adoption of Varieties with Zero EPR As Uniform EPR Rates are Introduced (Uniform-Actual)

Source: As calculated by Author

As presented in Figure 5.6, in the case of free varieties, a switch to uniform EPR pricing decreases average adoption since they are no longer free. That is intuitive and an expected result.

In summary, the differences in adoption under two scenarios are predictable in pattern. The simulated counterfactual of uniform EPR rates show that when there is no price difference between varieties, when there is a uniform EPR rate farmers will choose better, higher yielding varieties sooner and dis-adopt older varieties sooner. The welfare impact of this shift in adoption pattern is estimated in section 5.4.

5.4 Welfare Implications of Factual and Counterfactual EPR Systems

As explained above, the change of the EPR system from varying to uniform across wheat variety rates has an impact on adoption of wheat varieties.

5.4.1. Yield

The different varieties choice under a uniform EPR rate system translates directly to change in weighted average yield. This section analyzes the impact of uniform EPR rates on weighted average yield. Since uniform EPR rates tend to increase and speed up adoption of better varieties, it is expected that as a result of moving to uniform EPR rates, average yield of adopted varieties would increase.

The yield for each variety in this dataset is expressed as a percentage of Wyalkatchem, and is established through a number of randomised small plot variety trials, and reported by DAFWA (various years) and Wheat Variety Guide Western Australia. Using these relative yield indexes and the observed and counterfactual adoption curves reported in Section 5.3, the weighted average yield for Australian data and weighted average yield for the counterfactual scenario have been calculated.

$$\overline{y_t} = \sum_i^n \%A_{ti} * y_i \quad (5.3)$$

$$\overline{y_t^U} = \sum_i^n \% A_{ti}^U * y_i \quad (5.4)$$

$$\Delta\bar{y}_t = \overline{y_t^U} - \overline{y_t} \quad (5.5)$$

$$\%\Delta\bar{y}_t = \frac{\Delta\bar{y}_t}{\overline{y_t}} \quad (5.6)$$

where:

$\overline{y_t}$ = observed weighted average yield in year *t*;
$\%A_{it}$= observed percent adoption of variety *i* in year *t;*
y_i = yield of variety *i* expressed as a percentage of Wyalkatchem;
$\overline{y_t^U}$= weighted average yield in year *t* with counterfactual uniform EPR;
$\%A_{it}^U$= percent adoption of variety *i* in year *t* with counterfactual uniform EPR;
$\Delta\bar{y}_t$ = the change in weighted average yield in year *t* with counterfactual uniform EPR;
$\%\Delta\bar{y}_t$= the percentage change in weighted average yield in year *t* as counterfactual uniform EPR rates are simulated;

The weighted average yield, weighted average yield in counterfactual scenario with uniform EPR rates and the percentage change in weighted average yield are reported in Table 5.1 and presented in Figure 5.7.

Table 5.1 Weighted Average Yield Ratios under Two Scenarios and its Percentage Increase.

Year	Weighted Average Yield With Actual Adoption	Weighted Average Yield With Uniform EPR rates	Percentage Change in Weighted Average Yield
1985	68.97252	68.97252	0
1986	69.43426	69.43426	0
1987	69.76948	69.76948	0
1988	70.40245	70.40245	0
1989	70.92088	70.92088	0
1990	71.14377	71.14377	0
1991	71.30003	71.30003	0
1992	71.56631	71.56631	0
1993	70.83248	70.83248	0
1994	70.87259	70.87259	0
1995	71.46242	71.46243	0
1996	71.83659	71.83659	0
1997	73.02063	73.02063	0
1998	75.86501	75.86501	0
1999	84.91756	84.96505	0.06%
2000	90.20017	90.27077	0.08%
2001	92.79317	92.91394	0.13%
2002	94.15453	94.17561	0.02%
2003	94.0378	94.25407	0.23%
2004	95.74261	96.37612	0.66%
2005	96.03984	96.78516	0.78%
2006	96.05281	96.80071	0.78%
2007	96.36845	97.04037	0.70%
2008	96.35403	96.85237	0.52%
2009	96.33533	96.9311	0.62%
2010	97.30229	97.88046	0.59%
2011	98.36986	98.88115	0.52%

Source: Author based on data

To analyze weighted average yield under a uniform EPR rate system only varieties adopted in Western Australia were used. Until 1998, varieties adopted in Western Australia did not have EPR rates attached to them. Therefore, the change to a uniform EPR system does not affect observations until 1998. Starting in 1998, as a result of using uniform EPR rates, adoption of varieties change. As uniform EPR rates are applied, adoption changed and resulting weighted average yield changed. As expected, uniform EPR rates increase weighted average yield. Under uniform Price, growers don't have price incentive to buy lower yielding varieties; therefore, they adopt higher yielding varieties. Discussed weighted average yields under both scenarios are presented in Figure 5.7. The difference in weighted average yield between two scenarios is on average 0.65% since 2004.

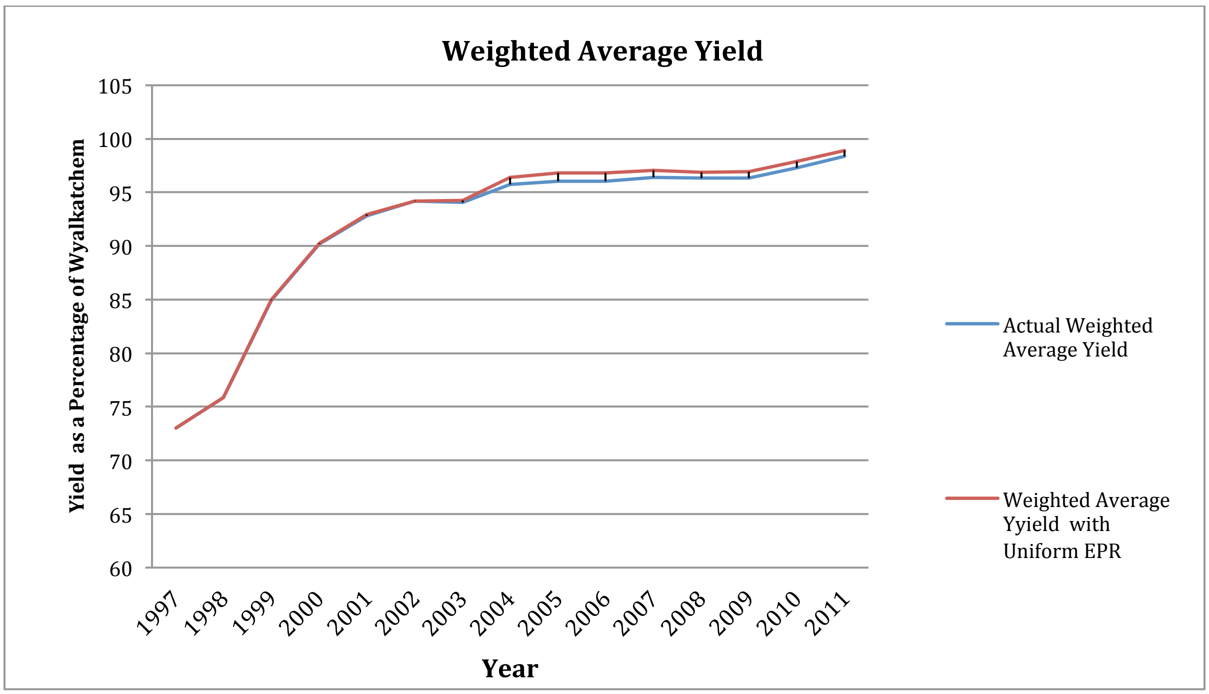


Figure 5.7 Weighted Average Yield under Varying and Uniform EPR Rate Systems

Source: As calculated by Author

The change in weighted average yield as uniform EPR rates are simulated is presented in Figure 5.8.

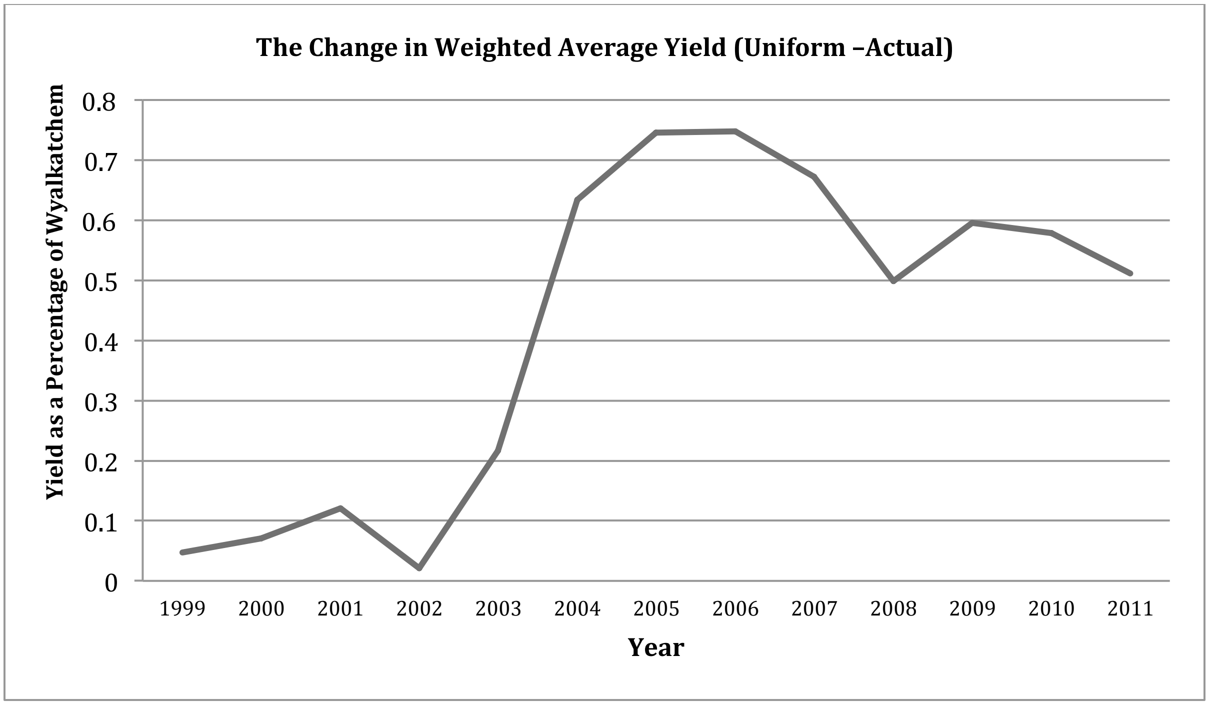


Figure 5.8 The Change in Weighted Average Yield (Uniform –Actual)

Source: As calculated by Author

As stated above, the obtained change in weighted average yield is on average 0.65% since 2004. To put it into perspective of increase in total production and value of that increase, Table 5.2 introduces total production and total counterfactual production as well as value of increase in production and revenue for breeders under a varying EPR system.

Table 5.2 Value of Increase in Production with Uniform EPR rates

Year	Total Production in WA in '000 tonne	GVP (AUD/t)	Value of WA Wheat Production in 000 AUD	Total Counterfactual Production in '000 tonne	Value of increase in production in '000 AUD	Revenue from EPR in WA in '000 AUD
1999	9,004.1	195.14	2,551,526.84	9,009.71	982.52	23.25
2000	5,814.4	232.06	1,884,746.02	5,818.95	1,056.02	188.75
2001	7,759.9	261.60	2,735,294.83	7,770.00	2,642.07	429.19
2002	4,046.9	265.68	1,408,592.14	4,047.81	240.81	252.18
2003	11,070	215.67	3,039,685.06	11,095.46	5,490.67	2,000.72
2004	8,619	197.06	2,088,205.55	8,676.03	11,238.20	4,813.70
2005	9,088.1	202.75	2,165,502.20	9,158.63	14,299.67	8,107.75
2006	5,134.3	241.96	1,389,487.91	5,174.28	9,672.89	5,588.28
2007	5,820.2	389.99	2,431,364.98	5,860.78	15,826.32	6,623.73
2008	8,266.5	281.09	2,340,572.10	8,309.25	12,017.95	9,265.74
2009	8,114.1	218.26	1,796,295.40	8,164.28	10,952.18	10,510.80
2010	5,004.6	272.89	1,322,298.70	5,034.34	8,114.84	8,246.51

Source: As calculated by Author

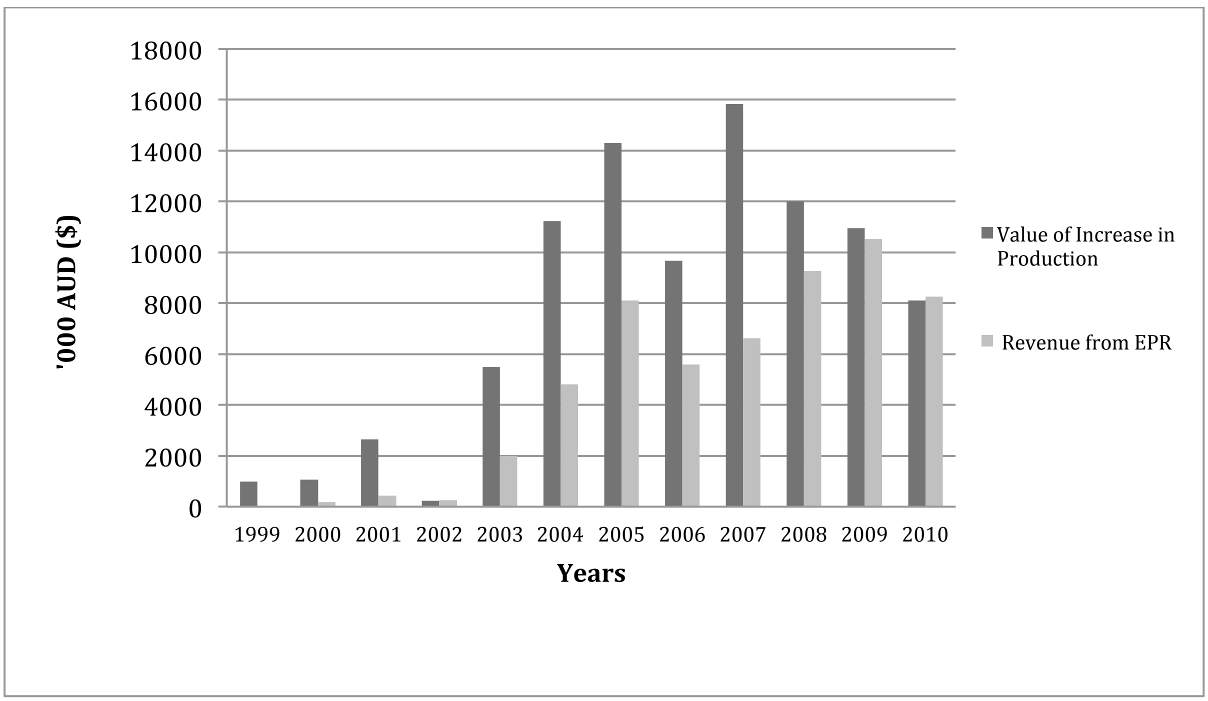


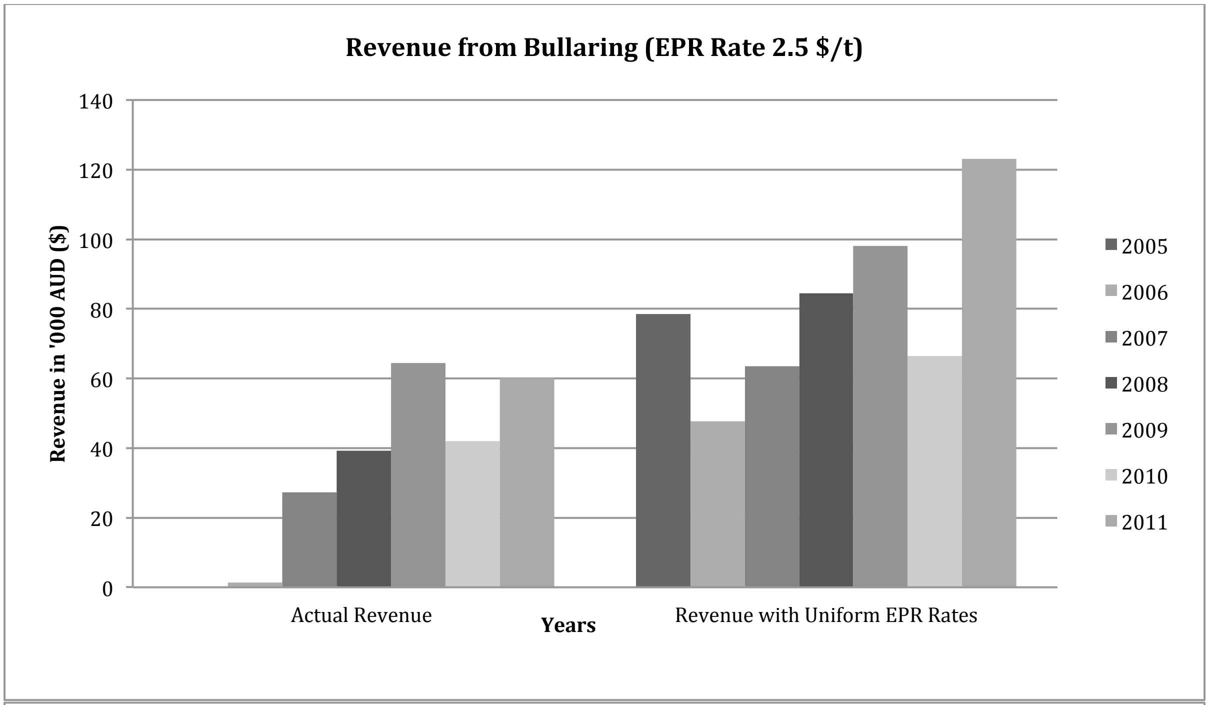
Figure 5.9 Value of Increase of Production under Uniform EPR Rates and Revenue from varying EPR rates

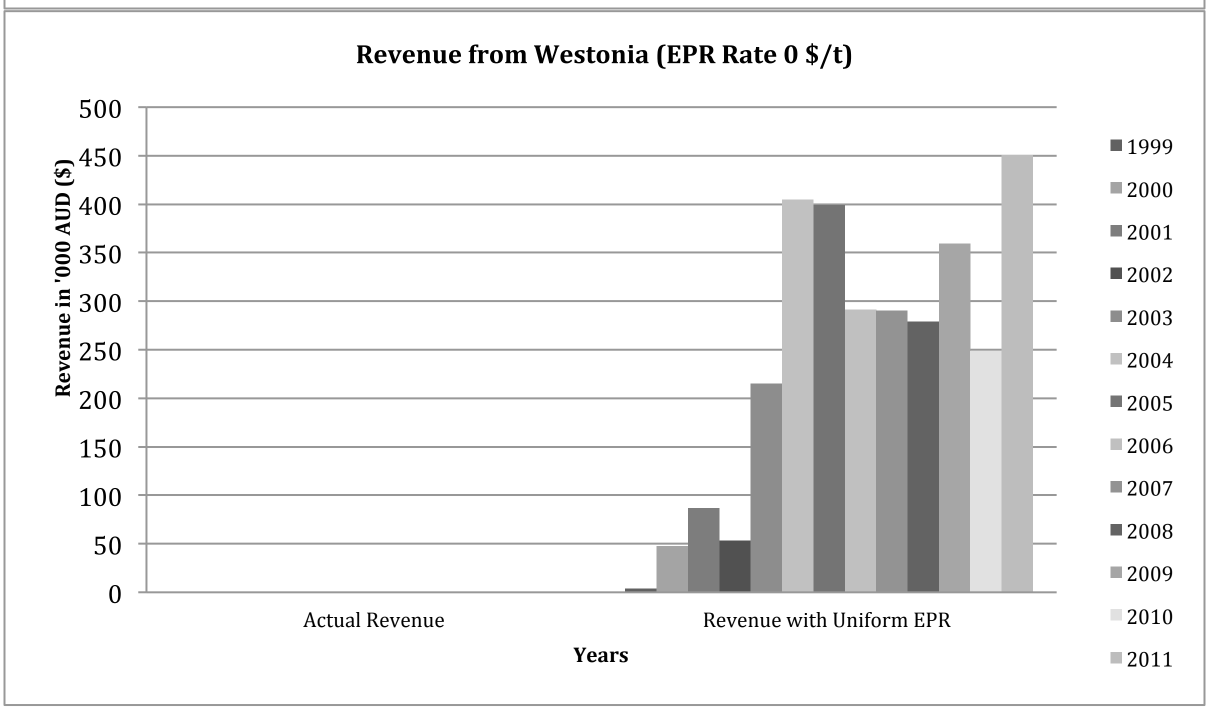
Source: As calculated by Author

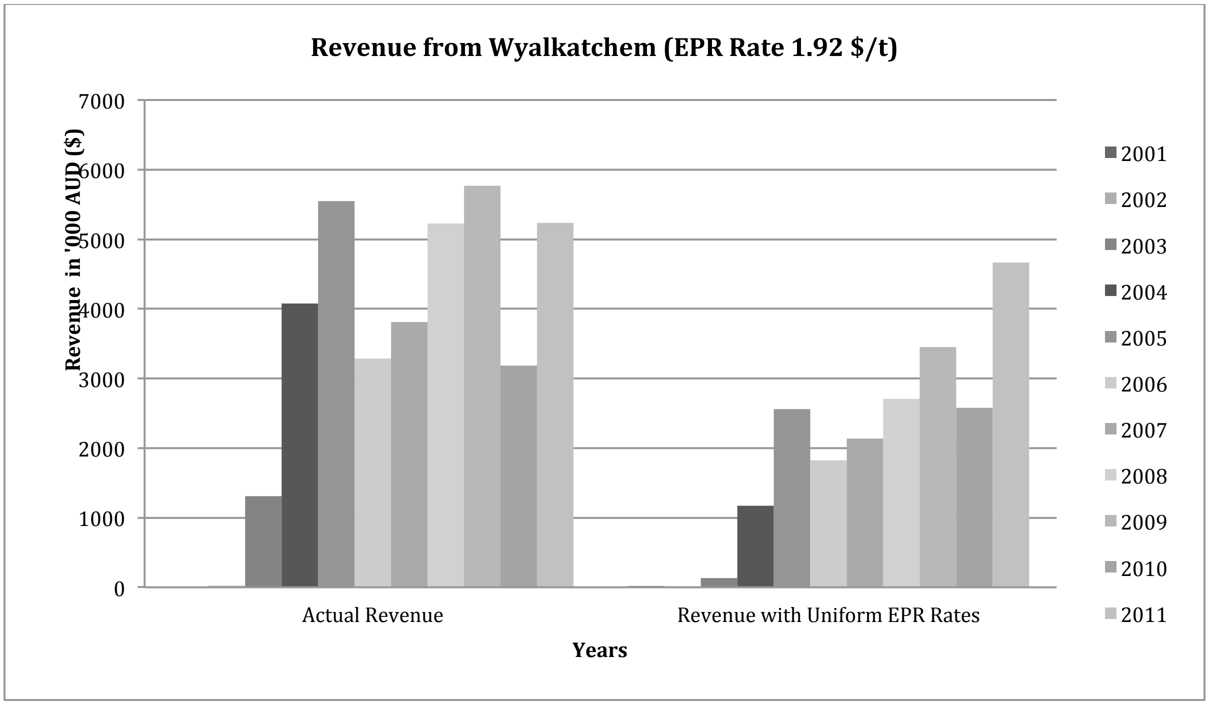
As can be observed in Table 5.2 and Figure 5.9, the market value of increase in production using gross value of production in AUD per tonne reaches 15.8 million AUD in 2007. The value of increase in production exceeds value of revenue for breeders from EPR. Revenue for breeders from EPR reaches 10.51 million AUD in 2009 and in 2007 6.6 million AUD. That increase is significant and suggests under a uniform EPR rate system farmers could afford to pay double EPR rates and have the same or higher economic gain as they do under a varying EPR rate system. Therefore, uniform EPR rates system appears to be much more efficient.

5.4.2 Revenue of Breeding Companies

Although uniform EPR rates were chosen at the level that provides the same total breeder's revenue per year for both systems, the change to uniform EPR rates affects revenue from individual varieties. The revenue from four varieties; Bullaring, Camm, Westonia, and Wyalkatchem, were calculated under both EPR rate systems and are presented in Figure 5.10. Westonia, Wyalkatchem, and Bullaring were the highest yielding varieties when introduced to the market. Camm is just an average variety.


Revenue from Bullaring (EPR Rate 2.5 $/t)
Revenue in '000 AUD ($)
140
120
100
80
60
40
20
0
Actual Revenue
Years
Revenue with Uniform EPR Rates
2005
2006
2007
2008
2009
2010
2011


Revenue from Westonia (EPR Rate 0 $/t)
Revenue in '000 AUD ($)
500
450
400
350
300
250
200
150
100
50
0
Actual Revenue
Revenue with Uniform EPR
Years
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011



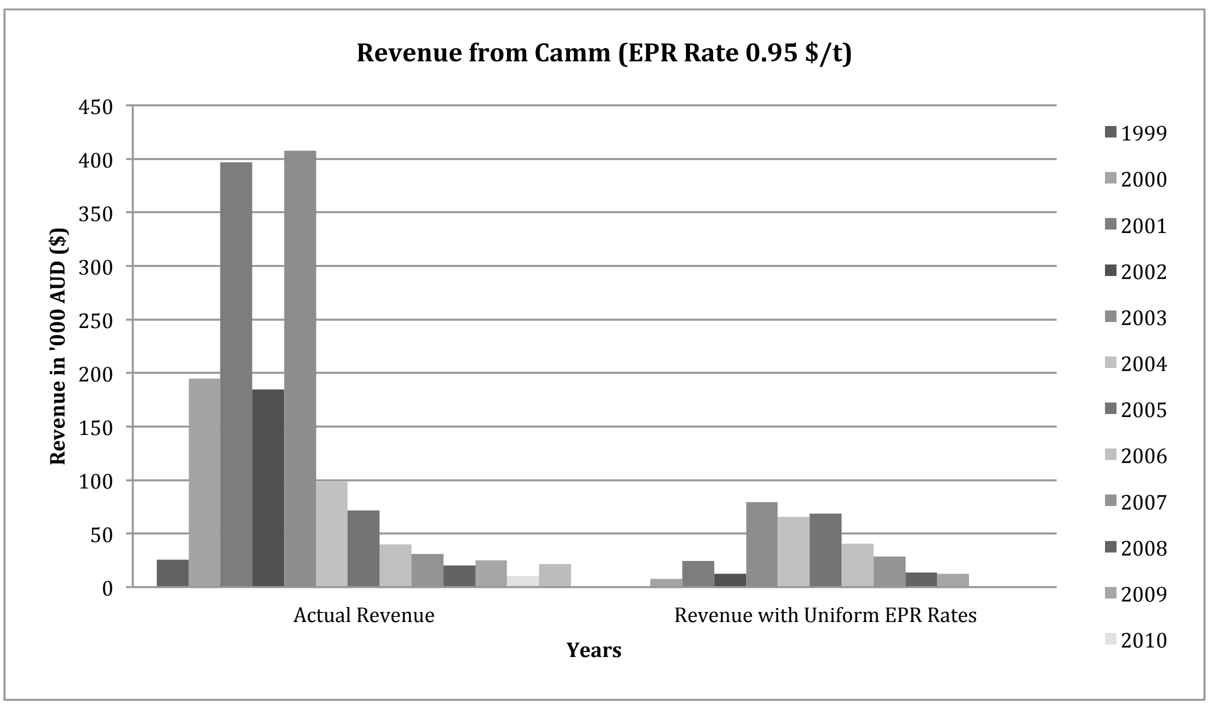


Figure 5.10 Revenue for Varieties with Varying and Uniform EPR Rates

Source: As calculated by Author

As presented in Figure 5.10, the change of EPR system affects revenue from varieties.

Revenue changes because of price quantity effect. Price and adoption are negatively correlated, consequently, whether uniform EPR rates cause an increase or decrease in revenue from a variety depends on whether the EPR rate of that variety increased or decreased under uniform EPR rates and how strongly that change affected the adopted quantity.

Among wheat varieties adopted in Western Australia, there are three cases of change as the uniform EPR rate is analyzed. The first case is a free variety, Westonia. As a uniform EPR rate is introduced, adoption of the variety decreases, however, it does start to generate revenue.

The second case includes varieties with an EPR rate attached to them and relatively high adoption. That type of varieties, such as Camm and Wyalkatchem, are the most representative since currently all new varieties have EPR rates attached to them. These varieties have price inelastic demand. For Camm, revenue under a uniform EPR system is much lower than in the actual situation. The EPR rate of Camm is 0.95$/t, which is more than the uniform EPR rate until 2005. The inelastic increase in adoption due to the decrease in EPR rate is insufficient to offset the losses from the lower price. In the case of Wyalkatchem revenue also decreases under uniform EPR rates.

Finally, the third case includes varieties with EPR rates attached to them with low adoption rates. These types of varieties, such as Bullaring, have an elastic response to price change. For Bullaring, revenue under the uniform EPR system increases. Given that Bullaring has an EPR rate of 2.5$/t, which is higher than a uniform EPR rate, higher revenue suggests an elastic response to price change. Bullaring has a small market share and relatively high EPR rate that is responsible for price elastic demand at this point.

In summary, although in the above simulation there are cases of increased revenue under the uniform EPR rate system, on average, varieties in Western Australia have price inelastic demand, therefore, since uniform EPR rates tend to be lower than varying EPR rates, the revenue from individual varieties, in most cases, is going to decrease as a result of the uniform EPR rate system. However, over time, superior, higher yielding varieties are expected to have the highest EPRs. Uniform EPRs will accelerate the adoption of these varieties. Therefore, firms that can introduce new, higher yielding varieties will have much higher revenue than owners of older, lower yielding varieties. Uniform EPR rate takes the risk out of setting new EPR rates.

Whether the firm will have higher or lower revenue under a uniform EPR rate system relative to varying EPR rate system depends on the level of uniform EPR. As presented in the previous section, uniform EPR rates generate increase in total production of high value. Therefore, farmers can afford to pay higher EPR rates and still generate the same or higher economic gain, although breeding companies might have a power to negotiate a higher level of uniform EPR rate than assumed in this analysis.

5.5 Possible Counterfactual Scenarios

The counterfactual scenario used for simulation and analysis in this Chapter is just one of many possible scenarios. A second scenario could include a uniform EPR rate that generates higher revenue from 1994 onward. Establishment of this uniform EPR rate system could overcome problem of slow growth of EPR rates, by creating profitable level at the moment of implementation of uniform EPR rates. Such a system would generate higher revenue with the reinvest revenue from year one; A third counterfactual scenario could be one without EPRs. This system would unable to generate sufficient incentives for private investment in R&D and would have to rely on public and producer funding of wheat breeding.

5.6 Summary and Concluding Comments

The objective of this Chapter was to analyze the impact of varying and uniform EPR rate systems on wheat varieties adoption patterns, weighted average yield, and revenue of breeding companies. The theory suggests that whether change to uniform EPR rates lead to an increase or decrease of economic welfare is an empirical question. The study has been conducted using the data from Western Australia, covering years 1984-2011 and estimation results from Chapter 4 of this dissertation. The counterfactual scenario of wheat varieties adoption with uniform EPR rates has been simulated and analyzed.

Based on the obtained results, it can be concluded the change of EPR system from varying EPR rates to uniform EPR rates has an impact on adoption of wheat varieties in Western

Australia. The changes affect areas such as: speed and level of adoption and dis-adoption, weighted average level of yield generated by adopted varieties, and revenue for breeders/varieties owners. As expected, there is a pattern of faster adoption of varieties when uniform EPR rates are present relative to the market with varying EPR rates. Higher prices of better varieties under a varying EPR rate system delay and limit adoption of those varieties. Under uniform EPR rates, price differences between varieties disappear, therefore, farmers do not have a price reason to choose a lesser variety and consequently choose better varieties sooner than before. Dis-adoption of varieties also occur faster with uniform EPR rates since producers adopt new varieties sooner, and therefore, dis-adopt old varieties.

The analysis shows that a uniform EPR rate system increases weighted average yield and total production. The value of increase in total production is high and reaches a 15.8 million AUD in 2007 that is higher than breeders' revenue from varying EPR rates that was 6.6 million AUD in 2007. This suggests under the uniform EPR rate system, farmers could afford to pay almost double and still obtain the same economic gain, which suggests the uniform EPR rates system is attractive and efficient.

The obtained results show a mixed impact of uniform EPR rates on revenue from varieties depending on initial pricing of those varieties. On average, wheat varieties had inelastic demand and a switch to uniform EPR rates, which were on average lower than variable EPR rates, decreased revenue from individual varieties. However, over time, better varieties tend to have higher prices and the uniform EPR rate system accelerates adoption of better varieties. Therefore, their owners are going to have higher revenue relative to owners of lesser varieties. Whether revenue under uniform EPR rates is going to be higher or lower than under a varying EPR rate system depends on the level of uniform EPR rates. Since uniform EPR rates generate a high value increase in production, farmers can afford to pay much higher EPR rates and still obtain the same or higher economic gain. The breeding companies can bargain higher uniform EPR rates than were assumed in this research.

The effects of change to a uniform EPR rate system are consistent with expectations. Generally, total welfare under the counterfactual scenario with uniform EPR rates is higher.

Chapter 6

SUMMARY and CONCLUSIONS

6.1 Policy Implications

In the absence of strong Intellectual Property Rights (IPR) agricultural research output (knowledge) is a public good with limited incentives for private investment. The underinvestment in agricultural research is confirmed by the available empirical evidence, which suggests the returns to agricultural R&D though variable, are high on average. For example, Alston et al. (2000) conducted a meta-analysis of public agricultural research and reported an overall mean internal rate of return to agricultural R&D (Table 12, p.55) as 81.3 percent per annum and a median of internal rate of return equal to 44.3 percent.

The Agricultural Growth Act passed royal assent in February 2015 making Canada's law compliant with the International Union for the Protection of New Varieties of Plants 1991 (UPOV 91). The Act updates Canada's legislation from the former UPOV 78 framework. As Canada is implementing UPOV 91 and contemplates various ways to increase funding for agricultural R&D, especially wheat breeding, Australia and France presents models that should be considered.

Australia has a very successful wheat breeding and commercialization system, characterized by a higher intensity of research than exists internationally. The goal of this study was to explore the Australian system of delivering agricultural research development and extension by studying its key aspects in more detail. The country has a long history of levy funded research. The GRDC, created in 1990 and funded by a growers' levy of 1% of value of production and matched by government on a dollar for dollar basis up to 0.5 per cent of GVP paid on 25 crops, has played a pivotal role in the development of the wheat breeding industry. In the late 1990's, the GRDC began to seek public and private partners for creation of wheat breeding corporations. As a result of these actions, Australia now has four major wheat breeding companies, among which, three were established as public private partnerships with the GRDC.

With the establishment of commercial wheat breeding firms, the GRDC now mainly invests in agronomy and crop management practices, pre-breeding activities and in the breeding of niche crops where funding through EPRs is not achievable. GRDC is investing in projects of pre-breeding activities to make sure that adequate to industry needs; germplasm is developed and available on equal rights to all breeding companies.

The 1994 Plant Breeding Rights Act, which enabled breeders to charge EPRs, eventually created the revenue base required for the establishment of the 4P partnerships (Public, Producer, and Private Partnership). After introduction of the Plant Breeder Rights Act in 1994 in Australia, wheat varieties with EPR rates attached to them had to compete with older, free wheat varieties present in the market. This competition impacted the level at which EPR rates were set, and made EPR rates lower than they would be otherwise. By 2011, 15 years later, the EPRs for wheat varieties had reached a level sufficient to fund the breeding activities of AGT and InterGrain (Walmsley 2011). The most recent wheat varieties in Australia have EPR rates of $3.50 per tonne, which is approximately 1 per cent of value of production. As these varieties become fully adopted, the EPRs will generate profit for breeding firms. While it took some time to develop an effective collection system, and many more years for EPR rates for varieties competing with royalty free varieties to reach compensatory levels, EPRs allowed plant breeders to obtain a return on their investment. In this market-driven system, breeding companies receives a strong financial message in the form of producer adoption of successful varieties.

As varieties improve over time, the ability to charge higher EPR rates also increases. In the hybrid crop sector, which is similar to wheat breeding since it is dominated by the private sector, strong IPRs have resulted in seed costs approximately 10% of the gross value of the crop, generating large rents for breeding firms. If in the future EPR rates behave in the way similar to hybrid seed prices, this would create a large cost for producers with an uncertain rate of reinvestment in R&D. The excessive prices create Dead Weight Loss and inefficiency in the market. A critical question arises; what is the future of EPR rates in Australia? The public, producer and private identity of shareholders in the 4P wheat breeding firms brings up a question of how those wheat breeding companies are going to behave in the long run; whether they will be profit maximizing, social surplus maximizing, or act in some other way as mixed ownership structured enterprises.

Pricing done by these breeding companies was analyzed in the theoretical model of pricing behaviour using a model similar to Malla and Gray (2005). In each scenario, there are two independent firms in an oligopoly selling differentiated wheat varieties to heterogeneous farmers. In the first scenario, the oligopoly is made up of two private firms. In the second scenario, a privately owned firm competes with a publically owned firm. In the third scenario, there is a producer owned firm competing with a private firm.

In the first scenario, where two private companies compete with each other in the market for wheat varieties, prices of the varieties are at a higher level than if one of the companies was public or producer owned. The social economic surplus is also lowest in the first scenario.

The second scenario, where the oligopoly is made up of a public or taxpayer owned company competing with a private company reveals some novel results. In order to maximize social surplus, the public company should price above marginal cost, given that the competing private company prices above marginal cost. This result is related to the theory of "Second Best". The distortion from charging prices above marginal cost by the private company can be reduced by creating second distortion and charging a price above marginal cost by the public company. Furthermore, if the public company is given a Stackelberg leading position, both companies will still price above marginal cost, but prices will be lower and total surplus is increased. Again the theory of "Second Best" applies to this outcome. Adding distortion by interfering in the market and granting the public company a Stackelberg leading position reduces total distortions in the market. In this scenario, prices are lower than in the first scenario and social surplus is the highest among all three scenarios.

Finally, the third scenario analyzes an oligopoly model with a producer owned company competing with a private company. The results show that the producer owned company, in order to maximize growers' and breeder's surpluses in the market for variety, price their variety at zero. Consequently, under the third scenario, prices are the lowest among all three scenarios. The simulated total surplus is higher than in scenario one with two private companies but lower than in scenario two with a public and private company in the market. Notably, at a price of zero, the producer owned company is not generating any revenue that could be used for reinvestment in R&D.

Based on the analysis, it can be concluded that different objective functions related to firm ownership do affect pricing behaviour. Therefore, the way Australian wheat breeding companies will act, whether as a private company, public company, or producer owned company, will affect the welfare of Australian wheat growers and breeders. Public and producer ownership of a breeding program reduces prices in the market relative to prices with private ownership of breeding programs. Consequently, the GRDC's and state governments' power to influence InterGrain or AGT pricing behaviour might enhance social surplus by mitigating price increases over time. Additionally, over time, as wheat breeding programs will deliver higher yielding varieties, the importance of ownership is expected to be greater. Divergence in total surpluses and prices among scenarios of wheat-breeding programs' ownership is expected to grow. As Canada introduces UPOV 91 and is assessing various options to fund wheat breeding, including public sector and producers in the ownership of wheat breeding, it has the potential to enhance price competition and social surplus.

With the goal of understanding how EPRs affect adoption, this dissertation econometrically analyzed wheat varieties adoption and impact of EPR rates on adoption decisions. EPR rates are charged on wheat varieties and are essentially a price of variety; therefore, EPR rates are directly related to the profitability of an innovation. Since profitability is one of the most important determinants in the decision to adopt innovation (Griliches 1960; Lindner 1987), EPR rates are an important factor in the decision to adopt innovation. Based on existing literature, the lifecycle adoption model similar to Dahl et al. (1999) was chosen as the most suitable model to analyze wheat adoption in Western Australia. The model was estimated using OLS estimator and tested for collinearity and heteroskedasticity. Robust standard errors were used to correct for heteroskedasticity. The adjusted model was chosen as the best predicting model with many of the potential explanatory variables found to be statistically significant and the model as a whole was statistically significant with adjusted R squared 50%. The estimated adoption model for wheat varieties in Western Australia fit well. Using estimation results, a predicted average adoption model was simulated and suggests that adoption of wheat varieties in Western Australia follows a standard product lifecycle. For average variety, the top of adoption curve is achieved 9 years after variety release and reaches 11.02% of market share. The average variety stays in the market for about 20 years. The marginal effect of time on variety adoption was also simulated holding all other variables constant. In this case the top of adoption, based only on time since release, is obtained in about 15 years of variety existence in the market and reaches 9.89% of market share. Comparing these two adoption curves implies that the explanatory variables in the model speed up and increase adoption patterns relative to a pure time trend pattern.

The EPR rates were found to have a negative, statistically significant at 5% of significance level, impact on variety adoption. The estimated coefficient suggests that an increase in EPR rates by one dollar per tonne cause market share of the variety expressed as a percentage of total area of wheat to decrease by 0.59% of total area seeded to wheat. This estimation result suggests price inelastic demand for average variety with elasticity of -0.13.

Finally, the dissertation analyzed the impact of counterfactual uniform EPR rates system on wheat adoption and created welfare, using data from Western Australia. As Canada is implementing UPOV 91 and planning to introduce its own EPR system, the impacts of an EPR rates system on wheat variety adoption and on economic surplus becomes an important consideration. This study simulated the adoption of Australian wheat varieties under a hypothetical "counterfactual simulation" of uniform EPR rates. This simulation enabled comparison of variety adoption rates and economic welfare impacts under the uniform EPRs, currently used in France, to those observed under the variable EPR rate systems employed in Australia.

The royalty collection system in France has overcome some difficulties inherent in the Australian approach. There are five apparent advantages: 1) Since the uniform EPR rate applies to the sale of all wheat varieties, it is relatively simple to administer; 2) The uniform rate applied across varieties eliminates any incentives for producers to mis-declare varieties; 3) The uniform royalty rate accelerates the adoption of traits with exceptional value by putting these varieties on an equal price footing with all existing varieties; 4) This latter effect enables a move to compensatory royalty rates even when prior varieties exist in the market place. Uniform EPR rates does not require such a long time as varying EPR rates (15 years) to get to economical level, right from the beginning it enable generating revenue since rate is negotiated between breeders and growers. 5) Finally, because the EPR rate is negotiated between the seed industry and the farm leaders every three years, the system eliminates any ability of the concentrated industry to charge excessive royalty rates.

Despite the apparent advantages of negotiated uniform EPR rates, there are some inherent weaknesses. First and foremost, this system takes royalty rate setting away from the control of individual owners of the varieties. Under some circumstances, this could reduce royalty revenue for specific varieties. Therefore, a uniform EPR rate may provide less than adequate compensation for the development of niche varieties. In contrast, the Australian model allows developers of niche varieties with less area to charge more per tonne (Gray and Bolek 2011). While negotiated uniform EPR rates can prevent the inefficiency caused by excessive privately set royalty rates, if negotiated rates are too low, it could imply a smaller share of benefits to seed companies leading to suboptimal research investment.

The theory suggests that whether change to uniform EPR rates lead to an increase or decrease of economic welfare is an empirical question. In this study, to reduce the dimensions of the problem, the simulated uniform EPR rates are set at a level to be revenue neutral. In each year, the uniform EPR rates are set at a rate that generates the same royalty revenue as was historically collected in Western Australia using variable EPRs. For instance, in the 2004 year of the simulation, the uniform EPR is adjusted to generate 4.8 million AUD in revenue, which is equal to the actual 2004 EPR revenue.

Based on the obtained results, it can be concluded the change of EPR system from varying EPR rates to uniform EPR rates has an impact on adoption of wheat varieties in Western Australia. As expected, there is a pattern of faster adoption of varieties when uniform EPR rates are present relative to the market with varying EPR rates. Higher prices of better varieties under a varying EPR rate system delay and limit adoption of those varieties. Under uniform EPR rates, price differences between varieties disappear, therefore, farmers do not have a price reason to choose a lesser variety and consequently, they choose better varieties earlier. Dis-adoption of varieties also occurs faster with uniform EPR rates since producers adopt new varieties sooner, and therefore, dis-adopt old varieties.

The analysis shows a uniform EPR rate system increases weighted average yield and total production. The value of increase in total production is large and reaching a peak of 15.8 million AUD in Western Australia 2007. This estimated gain in economic welfare for switching to uniform EPR rates is 239% of the observed total breeder revenue of 6.6 million AUD in 2007. This result suggests that under uniform EPR rates farmers as a whole could afford to pay almost double and still obtain the same economic gain. That suggests a uniform EPR rate system is attractive and could provide significantly higher revenue for producers

The results show a mixed impact of uniform EPR rates on the revenue generated from specific varieties depending on initial pricing of those varieties. On average, wheat varieties had inelastic demand and a switch to uniform EPR rates, which were on average, lower than varying EPR rates, decreased revenue from individual varieties. However, since over time, better varieties tend to have higher prices, a uniform EPR rate system accelerates adoption of better varieties, therefore, their owners are going to have higher revenue relative to owners of inferior varieties.

Whether revenue under a uniform EPR rate system is going to be higher or lower than under a varying EPR rate system is going to primarily depend on the level of uniform EPR rates. Since uniform EPR rates generate a substantial increase in gross value of production, farmers can afford to pay much higher EPR rates and still obtain the same or higher economic gain. With this outcome perhaps breeding companies can negotiate and bargain for higher uniform EPR rates, thereby increasing their revenue base.

In summary, the pricing of wheat varieties has an impact on generated surpluses. The pricing is affected by ownership of the breeding program, and the presence of public and producer owned programs has a positive impact on welfare.

The uniform EPR rate system affects surpluses in the market and overcomes, to a certain extent, the problem of high prices in the market caused by private ownership. The uniform EPR rate system generates higher surplus in the market, is simpler to administer and can get to a desirable level of price sooner (right from the beginning) than the varying EPR rate system. Therefore the choice between varying and uniform EPR rate systems in Canada depends on who is creating the system. Producers are going to benefit from the uniform EPR system; breeding corporations are going to insist on the varying EPR rate system.

6.2 Further Research

While this study has analyzed several aspects of EPR rate setting, there are a number of aspects of EPRs that warrant further research.

First, given their economic potential, uniform EPR pricing systems merit further investigation. This dissertation empirically focused on the Australian EPR system and simulates the impact of hypothetical uniform EPR rates on the wheat market in Western Australia. However, the empirical analysis of an existing uniform EPR system is limited to a basic description of the French system. More empirical research on systems that have employed uniform or near uniform EPR rates could improve the understanding of the strengths and limitations of these systems. France's CVO system for bread wheat, the UK farm saved seed wheat royalty system, as well as some models of levy funded research breeding are all potential subjects of additional empirical work.

Second, despite the theoretical work done in Chapter Three of this thesis it is still unclear how EPR rates have been set by mixed ownership breeding firms and how they will be set over time. As time generates more data, an empirical study on how EPR rates are set and whether there was a structural change in pricing behaviour after privatization of wheat breeding programs warrants further research.

Third, the variety adoption model employed in Chapter Four lacked the data required to examine impact of yield stability on variety choice. Given other studies have found that yield stability influences variety choice, further empirical study is warranted.

Finally, reinvestment rates in R&D and direction of research in Australia open many new questions, which further research might address.

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Appendix A

Demand for Variety

Consider a group of producers, each of whom determine whether to buy a unit of seed from *Breeding Company A* or a unit of seed from *Breeding Company B*. Producers are differentiated with respect to land characteristic ψ· which they own**.** Each producer owns one unit of land. The analysis begins with a location model, which is in range ψ (ψ∈ [0, 1]). Assuming the price of output P is exogenous and equal to 1, for simplicity reasons, producers have profit function as follow:

$\pi_i^A = Y - \tau\,(\psi_i) - w^A$ if producer buy unit of seed of variety A (3.1)

$\pi_i^B = Y - \tau\,(1-\psi_i) - w^B$ if producer buy unit of seed of variety B (3.2)

Where:
Y- is a yield from variety A and B, assumed to be equal
τ – is yield discount rate
w^A- is seed royalty for variety A
w^B - is seed royalty for variety B

As presented on Figure 1, revenue for each grower using variety A is given by $Y^A - \tau\,(\psi_i)$, the curve is shifted down by price w^A which grower has to pay for variety A. The same idea applies to growers using variety B. The revenue for each grower using variety B, is given by $Y^B - \tau\,(1-\psi_i)$, the curve is shifted down by price w^B which grower has to pay for variety B. The shifted down curves are a profit functions. The intersection between profit functions for variety A and variety B is at a point where the grower is indifferent between variety A and B, because both varieties give her an equal level of profit. The indifferent grower is $\pi_i^A = \pi_i^B \Rightarrow \psi_A = \frac{\tau + w^B - w^A}{2\tau}$.

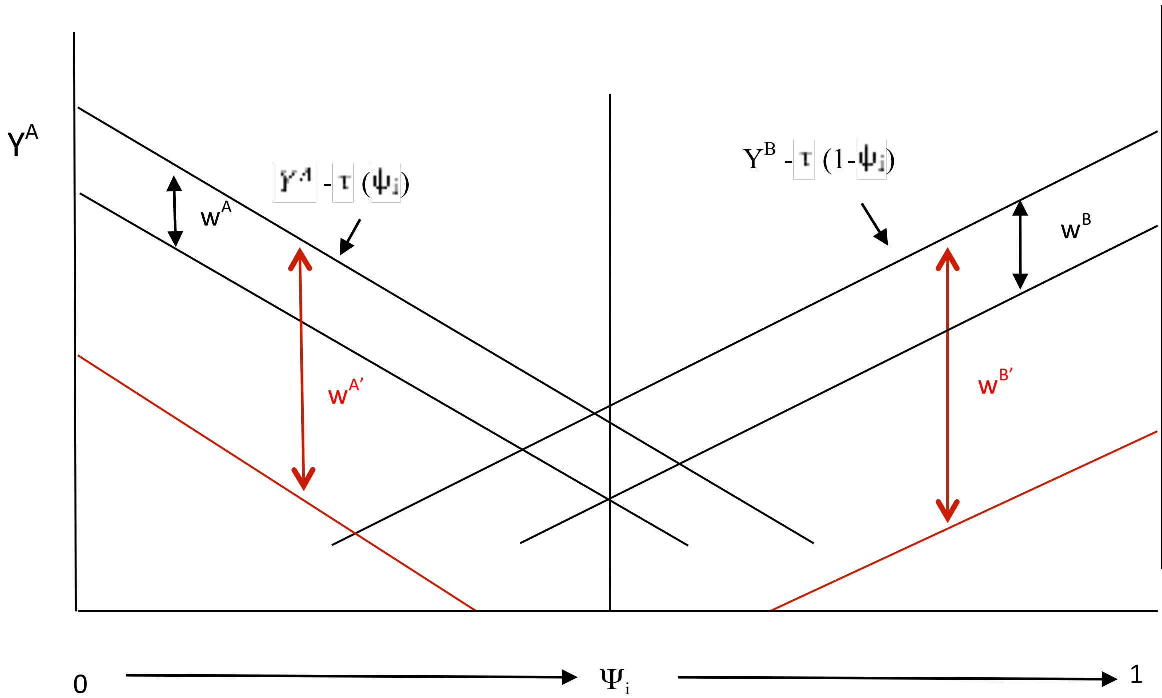

Figure 3 Location Model Limited to 0 - 1 Range

Assuming growers are uniformly distributed with respect to characteristic ψ, and recalling that each grower buys unit quantity of seed, the demand curve for variety A is $Q^A=\psi_A$

$$Q^A = \frac{\tau + w^B - w^A}{2\tau} \tag{3.3}$$

Demand for variety B is $Q^B=1- Q^A$.

$$Q^B = \frac{\tau - w^B + w^A}{2\tau} \tag{3.4}$$

If owner of variety A and owner of variety B are private companies, they are going to set their prices with the objective of profit maximization.

$\pi^A = Q^A(w^A) * (w^A - L)$, and symmetrically $\pi^B = Q^B(w^B) * (w^B\text{-L})$

Where:

L – is marginal cost, constant, known for both firms and equal 0.

Taking first order condition and solving for prices give best response functions:

$R^A = \frac{\tau + w^B}{2}$ (3.5)

$R^B = \frac{\tau + w^A}{2}$ (3.6)

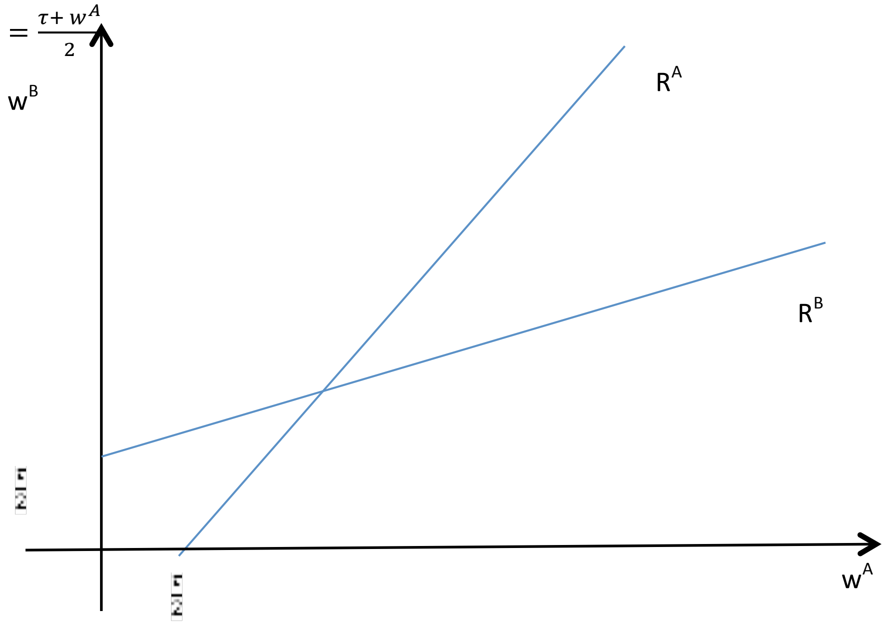

Figure 4 Best Response Functions

Best response functions are graphed on Figure 2. The intersection of best response function gives Nash equilibrium prices for company A and B. Nash equilibrium prices are:

$w^A = t$ (3.7)

$w^B = t$ (3.8)

Appendix B

Table 1 Collinearity Test – Full Model

Variable	**VIF**	**1/VIF**
(Time)2	**291.60**	**0.00**
(Time)3	**118.45**	**0.01**
Owner 6	**72.46**	**0.01**
Time	**49.27**	**0.02**
Owner 2	**35.67**	**0.03**
Owner 1	**28.36**	**0.04**
Owner 13	**16.48**	**0.06**
Owner 15	**13.72**	**0.07**
Owner 12	**12.53**	**0.08**
PBR	**11.20**	**0.09**
Owner 11	9.42	0.11
Yield Ratio	9.11	0.11
Mature 2	6.52	0.15
EPR	6.42	0.16
Mature 3	5.87	0.17
Mature 1	5.51	0.18
Disease Resistance	5.00	0.20
Free to Trade	4.24	0.24
Class 8	4.05	0.25
Mature 5	3.96	0.25
Class 6	3.54	0.28
Owner 7	3.37	0.30
Quality	2.95	0.34
Classification 3	2.59	0.39
GVP	1.15	0.87
Mean VIF	**28.94**	

Source: Author

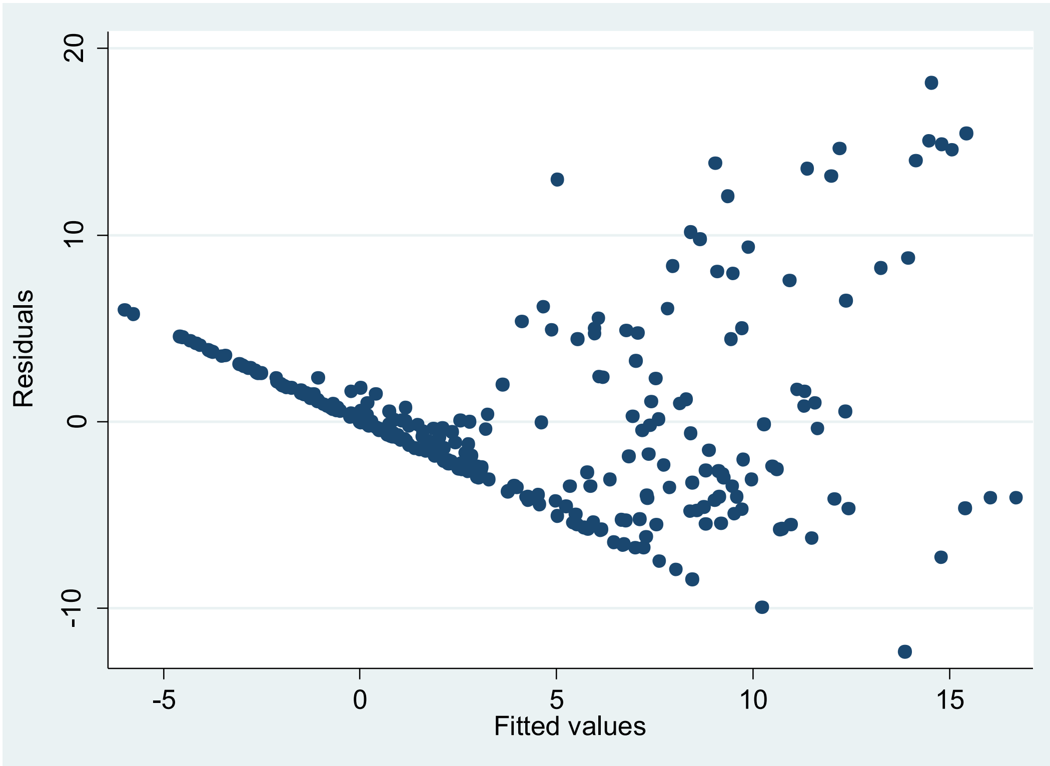

Figure 1 The Residuals Versus Fitted (Predicted) Values for Full Model.

Source: Author

As can be observed on Figure 1 above, the pattern of the data points is getting much wider towards the right end. Therefore, a more formal test for heteroskedasticity should be conducted.

The White test, test the null hypothesis that the variance of the residuals is homogenous. Therefore, if the p-value is very small, we would have to reject the hypothesis and accept the alternative hypothesis that the variance is not homogenous.

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of Adoption

chi2(1)=138.73

Prob > chi2=0.00

White's test for Ho: homoskedasticity

against Ha: unrestricted heteroskedasticity

chi2(143)=220.87

Prob > chi2 =0.00

Table 2 *Cameron & Trivedi's decomposition of IM-test*

Source	chi2	df	p
Heteroskedasticity	*220.87*	144	0.00
Skewness	*103.47*	25	0.00
Kurtosis	*10.59*	1	0.00
Total	*334.93*	170	0.00

Source: Author

The results show we have to reject the null hypothesis that errors are homoskedastic in the favor of the alternative hypothesis that there is heteraskedasticyty of error terms.

Additionally Table 3 introduces multicollinearity test.

Table 3 Multicollinearity test

Variable	VIF	SQRT VIF	Tolerance	R-Squered	Eigenval	Cond index
EPR Rates	2.90	1.70	0.34	0.66	8.38	1.00
Yield Ratio	8.15	2.86	0.12	0.88	2.41	1.86
Quality	1.81	1.34	0.55	0.45	1.94	2.08
Disease Resistance	2.98	1.73	0.34	0.66	1.31	2.53
GVP	1.11	1.05	0.90	0.10	1.20	2.64
$(Time)^2$	285.71	16.90	0.004	1.00	0.73	3.40
$(Time)^3$	107.25	10.36	0.01	1.00	0.58	3.81
Time	59.15	7.69	0.02	0.98	1.06	2.81
Mature 1	4.10	2.03	0.24	0.76	0.46	4.29

Mature 2	3.20	1.79	0.31	0.69	0.34	4.93
Mature 3	2.02	1.42	0.49	0.51	0.21	6.27
Mature 4	2.83	1.68	0.35	0.65	0.16	7.23
Class 3	2.05	1.43	0.49	0.51	0.08	10.21
Class 6	2.81	1.68	0.36	0.64	0.06	12.30
Class 8	2.31	1.52	0.43	0.57	0.05	13.07
Owner 2	5.77	2.40	0.17	0.83	0.02	18.85
Owner 11	1.53	1.24	0.65	0.35	0.01	23.73
Owner 13	2.21	1.49	0.45	0.55	0.00	72.86
Mean VIF	27.66				0.00	117.79

Source: Author

Condition Number 117.79

The condition number is a commonly used index of the global instability of the regression coefficients-- a large condition number, 10 or more, is an indication of instability. The large condition number in this estimation, 117.79, suggests there is instability of the model.

The collinearity statistics, including the tolerance level and the Variance Inflation Factors (VIF) are examined. The results as can be observed in Table 3 above indicate the tolerance levels for all of the variables (except *time*) are greater than 0.10 and the VIF statistics are all (except *time, Yield Ratio, Owner 2*) significantly less than a 5.0. These results indicate there is no huge collinearity between the independent variables. Yield Ratio is very important variable as economic theory and previous research suggest. Importance of Yield Ratio variable prevents us from removing it from the model due to poor collinearity test results.

Table 4 *Cameron & Trivedi's decomposition of IM-test.* Test for heteroskedasticity.

Source	chi2	df	p
Heteroskedasticity	278.36	120	0.00
Skewness	103.70	18	0.00
Kurtosis	12.26	1	0.00
Total	394.32	139	0.00

Source: Author

Table 5 Adjusted Model with EPR ratio

Variable	Coefficient	Std. Error	t-Statistic
Yield Ratio	30.43 **	6.60	4.61

EPR Ratio	-2.97**	1.08	-2.74
Time	1.42**	.21	6.85
$(Time)^2$	-.06**	.01	-4.77
$(Time)^3$	.001**	.00	2.93
Quality	.74**	.18	3.98
Disease Resistance	-.72	.46	-1.56
GVP	.005	.00	1.08
Owner2 (DAFWA)	4.92**	1.48	3.32
Owner11 (QDPI)	-4.57**	1.10	-4.13
Owner13 (University of Adelaide)	9.16**	1.18	7.80
Clas3 (AH)	-4.32**	.72	-5.94
Clas6 (ASFT)	-10.22**	1.26	-8.14
Clas8 (ASWN)	-3.97**	.95	-4.17
Matur1 (Long)	-2.19*	1.05	-2.09
Matur2 (Mid)	-1.31	.92	-1.41
Mature3 (Mid-Long)	-8.03**	1.29	-6.21
Mature4 (Short)	-5.33**	1.13	-4.71
Constant	-24.92**	7.92	-3.15

Source: Author

Observations 369

R-squared 0.52

* significant at 5% level; ** significant at 1% level